PHASE I
SITE HYDROGEOLOGIC INVESTIGATION AT THE ENTERPRISE AVENUE LANDFILL

REPORT OF HYDROGEOLOGIC RESULTS

Volume I

Prepared for

City of Philadelphia
Division of Aviation

29 April 1994

(b) (4)
[redacted]

Registered Professional Geologist
PG-481-G

Prepared by

ROY F. WESTON, INC.
1 Weston Way
West Chester, Pennsylvania 19380-1499

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF TABLES

SECTION 1
INTRODUCTION

The City of Philadelphia Department of Aviation (DOA) is planning the construction of a new 5,000-foot-long commuter runway (Runway 8-26) northeast of the Philadelphia International Airport. A portion of this runway be situated over the top of the Enterprise Avenue Landfill (EAL) located on the City of Philadelphia Southwest Water Pollution Control Plant property. The EAL is a delisted U.S. Environmental Protection Agency (EPA) Superfund site. In their review of the Environmental Assessment Report addressing this project, the EPA and the Pennsylvania Department of Environmental Resources (DER) requested the City of Philadelphia and the DOA undertake an extensive groundwater testing and analysis program at the site of the EAL. This program is being guided by a "Work Plan for the Hydrological and Geotechnical Investigation of the Enterprise Avenue Landfill" developed by DOA and its consultants in response to EPA and DER requests. This work also serves the EPA in its 5-year review of the remedial action taken at the EAL under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), which is being performed simultaneously with the Sole Source Aquifer review. DOA has retained Turner, Collie and Braden and its subcontractor Roy F. Weston, Inc. (WESTON®) to execute the program.

The Work Plan serves as guidance for the investigations at the EAL site. This work plan outlines the operations to be performed during the performance of both the geotechnical and hydrogeological studies. EPA approved the work plan on 25 March 1994.

This report is the first of three reports presenting the results of the Phase I hydrogeologic investigation. The second report will be produced after the second round of groundwater sampling laboratory results are received. The third, consisting of a detailed review of all of the data collected during this investigation, will follow.

1.1 BACKGROUND

1.1.1 Site Description and Location

The EAL site encompasses a total of 57 acres and is located within the City of Philadelphia adjacent to the Southwest Water Pollution Control Plant and at the eastern end of the Philadelphia International Airport. The landfill is bounded by Island Avenue on the south, Hog Island Road on the east, Enterprise Avenue on the west, and Interstate 95 on the north. A Conrail Railroad right-of-way bounds the landfill along the eastern and southern perimeters. Several underground petroleum pipelines (Colonial, Gulf, Sun) have rights-of-way along the eastern boundary of the landfill, and a major petroleum tanker unloading terminal and a large petroleum storage tank farm are located south of the landfill on the Delaware River. Figure 1.1-1 shows the geographic location of the EAL site.

1.1.2 Site History

1.1.2.1 Early History

The EAL is situated is an area that from the late 1700s through the early 20th Century was part of the extensive tidal marshlands along the Delaware River. The estuarine character of the site and the creeks that at one time flowed in and around the site have changed considerably as described below.

The major waterway through the area currently occupied by the EAL was the Back Channel of the Delaware. This channel separated Mud Island, where Fort Mifflin was located, from the mainland.

The Back Channel of the Delaware River had naturally silted in from 1776 to 1860 because of the extensive farming and mining on the upper reaches of the Schuylkill and Delaware Rivers. Sometime prior to 1910, the Back Channel no longer flowed into the Schuylkill River. Since 1910, the creeks have been rechanneled or replaced by drainage ditches and culverts. The low-lying land in this area has been extensively filled in for facilities such as the Philadelphia International Airport, tanker terminals, roadways, and industrial sites. The

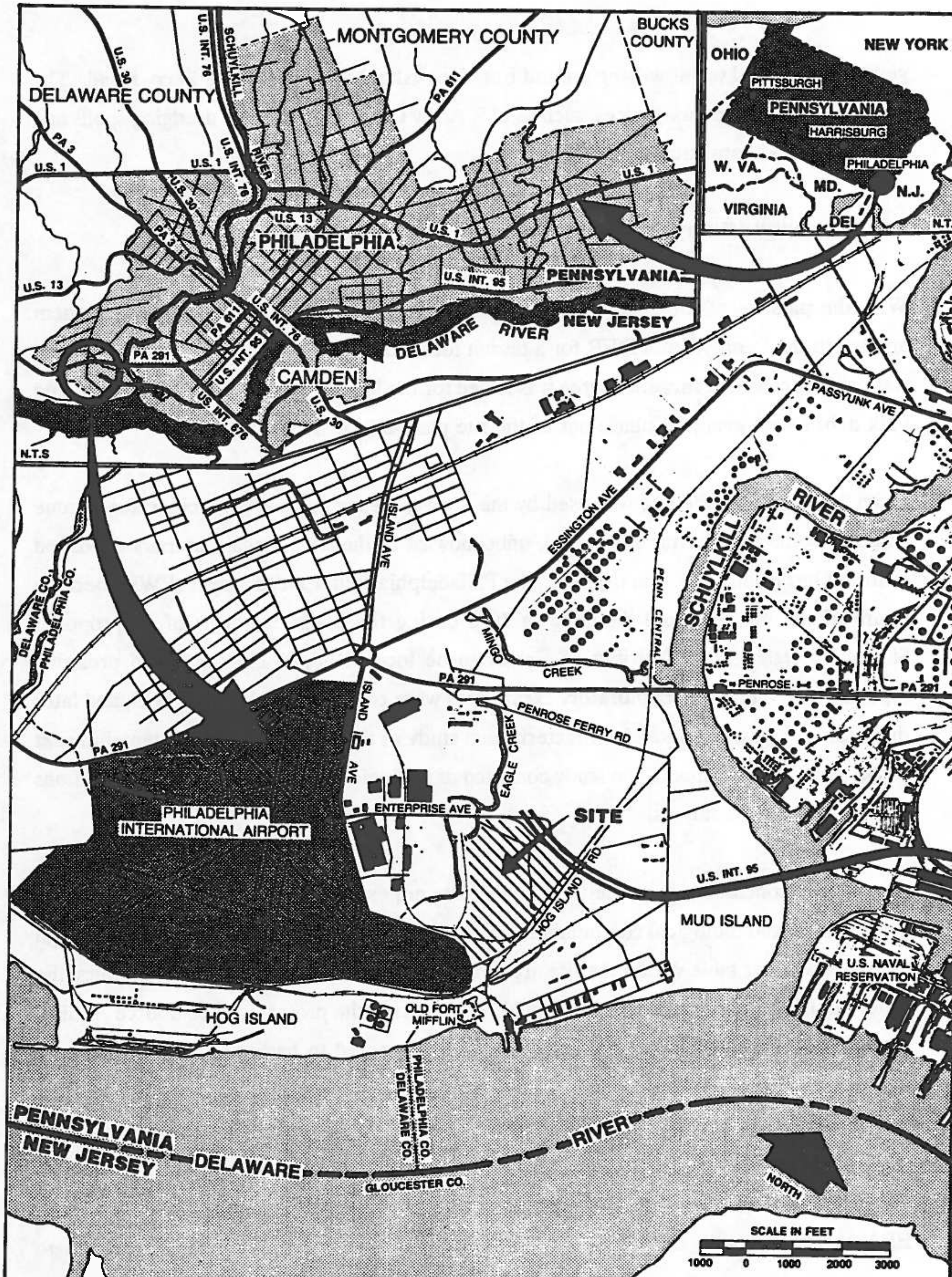


FIGURE 1.1-1 LOCATION OF THE ENTERPRISE AVENUE LANDFILL STUDY SITE

general area filled was low-lying ground from Hog Island toward Penrose Ferry Road. The fill came from numerous sources, such as U.S. Army Corps of Engineers dredging spoils and demolition and construction waste.

1.1.2.2 Landfill History

With the passage of the Solid Waste Act of 1970, the Philadelphia Streets Department applied to the Pennsylvania DER for a permit for landfilling at the site. Although a permit was never received, a consent decree was issued for the landfilling of incinerator residue and bulk debris with eventual phase-out of the site planned for the future.

From 1971 to 1976, the site was used by the Streets Department as an incinerator residue landfill. Sometime during this period, unbeknownst to the City, illegal dumpers deposited drums of hazardous waste on the site. The Philadelphia Water Department (PWD) became aware of the unauthorized dumping in 1978 during the planning stages of its proposed Sludge Processing and Distribution Center to be located at the EAL site and promptly reported it to the EPA. Exploratory excavations were conducted in January 1979, and later that year an investigation and characterization study of the potential environmental impact of the site was performed. The study consisted of geologic and hydrogeologic investigations and water quality analyses.

The study concluded that neither imminent nor substantial endangerment to the environment and biological communities existed in the area beyond the EAL site. Although the shallow water table within the site area was found to be contaminated with organics, the water quality of the underlying deep aquifer, comprising the protected Sole Source Aquifer of the Cretaceous Age PRM Formation (Kprm), appeared to be unaffected by the waste deposited at the site. The presence of a dense silty clay layer under the site mitigated the downward movement of contaminated water from the upper shallow water-bearing zone.

The City chose to remediate the site and pursue the responsible parties in court without EPA or Pennsylvania DER action. The objective for cleanup of the EAL site was to alleviate any potential contamination of the area by using the most environmentally sound and cost-effective means possible, focusing on the protection of the Kprm aquifer.

The remediation approach proposed by the City and approved by EPA and Pennsylvania DER was the excavation and removal of drums and associated contaminated soil from the site and their relocation to a federally approved landfill. A clay cap was placed over the site to limit infiltration of precipitation into the area where drums had been removed. The selected alternative addressed the need for a cost-effective and environmentally sound remediation and also left open the potential for future industrial use of the site, which was an important consideration for the City. Following the completion of cleanup activities, EPA proposed the site for delisting in December 1985. After the close of the public comment period, the site was officially delisted in March 1986.

After closure, Pennsylvania DER requested that the City perform 2 years of post-closure groundwater monitoring of wells surrounding the site to ensure that remedial action had been successful. This monitoring program was conducted from January 1985 through December 1987 and confirmed that no further degradation of groundwater had occurred.

The EAL site is currently unused. DOA, as part of its planned expansion of the Philadelphia International Airport, has proposed the construction of a new 5,000-foot-long commuter runway (Runway 8-26). The footprint for this proposed runway crosses the EAL. The proposed completion date for Runway 8-26 is the end of 1998.

1.2 CURRENT SITE CONDITIONS

1.2.1 Topography

The area surrounding the EAL was originally marsh and wetland with elevations at or near river level. This area has been filled extensively, resulting in topography that is extremely flat, with an average elevation of between 5 and 7 feet above river level. The construction of the EAL and the installation of the water treatment effluent structure for the Southwest Water Pollution Control Plant, located along the western edge of the EAL, has generated two topographic high points in this area. The elevation of these high points are from 12 to 14 feet above river level. Figure 1.2-1 shows the location of the site on the Philadelphia 7.5 minute topographic quadrangle and the features found in this area.

1.2.2 Drainage

Philadelphia is drained by the Delaware River and its tributaries. At Philadelphia, about 100 miles from its mouth, the Delaware is estuarine and has a tidal range of about 5.5 feet. According to Paulachok (1991), the average discharge of the Delaware River at Trenton, NJ, for 1913-84, unadjusted for diversion, was 11,700 ft^3/s (cubic feet per second). In dry years, however, the flow has been as low as 1,180 ft^3/s. During extended periods of low streamflow, the salt line, or location in the estuary where the chloride concentration equals 250 mg/L (milligrams per liter) has moved upstream as far as the Benjamin Franklin Bridge at Philadelphia (Toffey, 1982, p. 43).

The principal tributary to the Delaware River in this area is the Schuylkill River, which enters Philadelphia from the northwest and merges with the Delaware in southern Philadelphia. Confluence of these two streams occurs at this point approximately 1 mile to the east of the EAL. Downstream from the Fairmount Dam at Philadelphia (located approximately 3 miles north of the confluence of these two streams), the Schuylkill is estuarine.

In the immediate area of the EAL, there are a series of small ponds and streams (such as Eagle Creek) that carry surface water. Gross surface water flow direction seems to be northward toward Mingo Creek, a tributary of the Schuylkill River. During periods of heavy precipitation or during spring thaws, the surface and near surface interflow in the area is in the direction indicated above. However, due to the extreme flatness of the project area, many segments of the stream channels appear to be stagnant or still, especially during dry periods when the instream volumes are reduced.

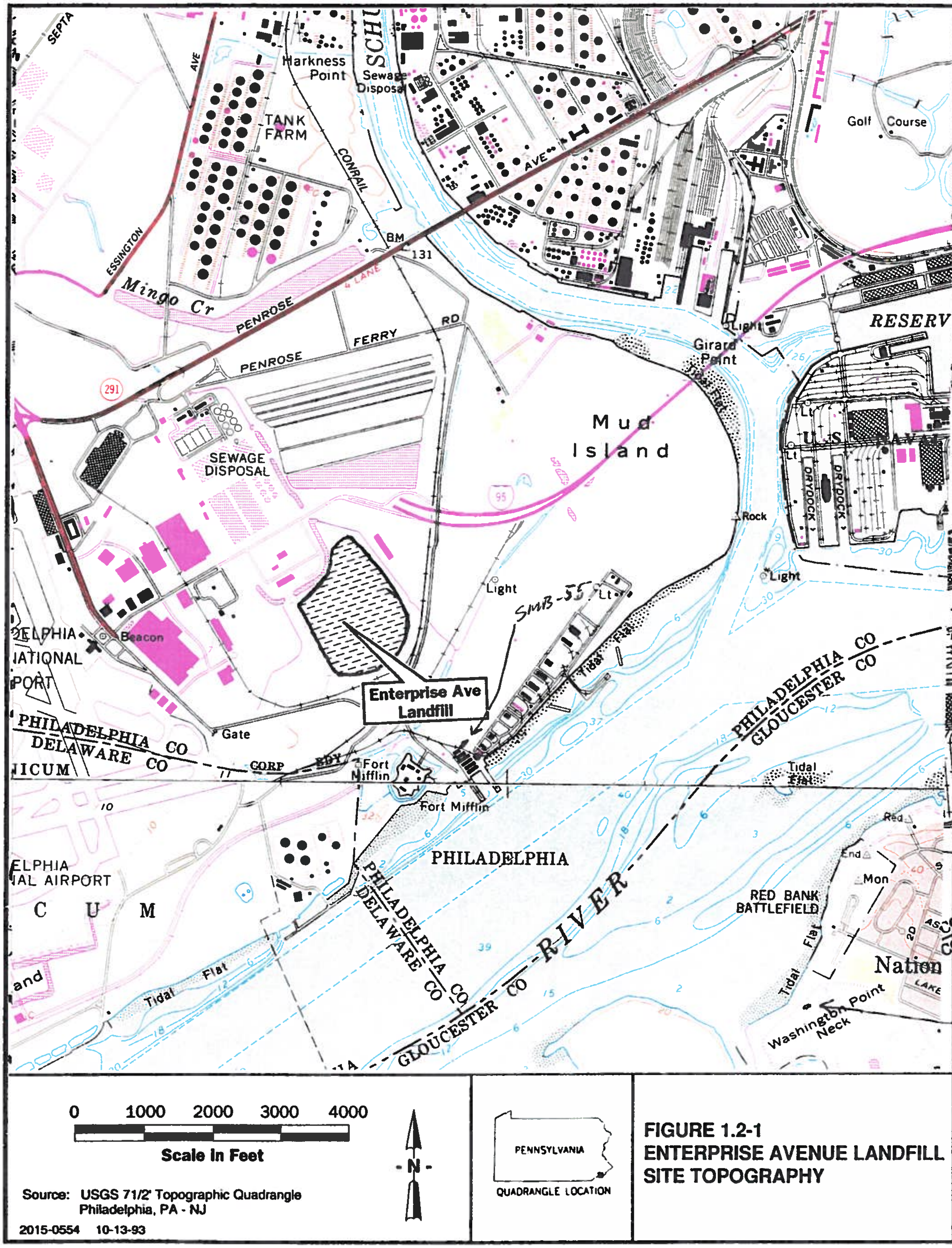


FIGURE 1.2-1
ENTERPRISE AVENUE LANDFILL
SITE TOPOGRAPHY

There are also numerous ponds and pools in the area surrounding the site that have no visible inlets or outlets. Some of these ponds seem to overflow after large storm events with a discharge occurring to the stream channels, but then rapidly recede into their original stagnant condition (P. Quigley, Personal Communication).

1.2.3 Climate

Philadelphia's climate is classified as a humid-continental type. It is influenced by the Appalachian Mountains to the west and the Atlantic Ocean to the east and is characterized by a large annual temperature range; cold winters dominated by low humidity air masses, hot summers dominated by medium to high humidity air masses, and ample precipitation.

Temperatures are generally moderate, and extreme temperatures seldom prevail longer than a few days. The long-term mean for temperature at the National Weather Service Station at Philadelphia International Airport is 12°C (54.7°F). The temperature encountered at the site during the Phase I field work portion of this investigation ranged from a low of -21.6°C (-7°F) to a high of 23.3°C (74°F).

Precipitation is moderate throughout the year. The long-term mean annual precipitation at Philadelphia is 39.93 inches. Generally, precipitation is distributed fairly evenly throughout the year, although slightly more falls during the late summer months. Much of the summer rainfall is due to thunderstorms; consequently, amounts throughout the area may vary a great deal.

1.3 SUMMARY

- The DOA is in the process of planning for the construction of a 5,000-foot-long commuter runway. A portion of this runway will be situated over the EAL.

- A hydrogeological and a geotechnical study are underway to determine if the construction and operation of the runway will have any adverse effect on the New Jersey Coastal Plain Sole Source Aquifer. A 5-year review of the remedial action taken at the EAL is being performed at the same time.

- The EAL encompasses an area of 57 areas. Prior to 1910, the site was marshland. Extensive filling of the area around the EAL has occurred over the last 60 years.

- The EAL was used as a landfill for incinerator ash in the 1970s.

- A problem with illegal dumping resulted in the EAL being listed on the EPA Superfund list. After a remedial action was performed, the site was delisted in 1985.

- Site topography is extremely flat. It is drained by a series of surface streams and ponds. Surface drainage is to the north toward Mingo Creek. Mingo Creek discharges into the Schuylkill River.

- The climate in the area is classified as a humid-continental type. Annual precipitation is about 40 inches per year.

SECTION 2

SITE INVESTIGATION

2.1 PREVIOUS INVESTIGATIONS

A series of investigations has been conducted in the area over the last four decades. These investigations include the following:

- A geology and groundwater study conducted by the Pennsylvania Geological Survey. Authored by Greenman et al. (1961), this study described the geology and groundwater conditions in the Coastal Plain area of southeast Pennsylvania. This investigation established the stratigraphic framework around the EAL, using a series of soil borings and well logs performed in the vicinity of the airport.

- A geotechnical investigation conducted by the Pennsylvania Department of Transportation as part of the planning for the I-95 Girard Point Bridge right-of-way (Modjeski and Masters, Engineers, 1964). This study was conducted in 1964 and included several hundred soil borings and a series of test pile logs. This study was conducted in the area directly north of well cluster MW-2. Data from this study were used to verify area stratigraphy, as well as to confirm the existence of a bedrock high to the east of the site.

- A report on the Upper Cenozoic Sediments in the Tri-state region (Owens and Minard, 1979). This U.S. Geological Survey Professional Paper (1067-1) details the origin and stratigraphy of the post-Cretaceous sediments such as the Trenton gravel and the recent additional deposits.

- A report investigating the EAL (Roy F. Weston, Inc., August 1979). This report detailed the installation of the first monitoring well network on and around the EAL site. The first groundwater quality data for this area were included in this report.

- A water table map of Philadelphia, Pennsylvania, 1979-1980. This Hydrologic Investigation Atlas, published by the U.S. Geological Survey (USGS) (Paulachok and Woods, HA-676, 1984) was prepared under a cooperative contract with the City of Philadelphia Water Department and established water table elevations around the EAL on the basis of measurements taken in 10 cased and uncased holes.

- A USGS Water Supply paper titled *Geohydrology and Groundwater Resources of Philadelphia, PA* (WSP-2346, Paulachok and Woods, 1991). This report synthesized the hydrological framework for Philadelphia and vicinity. While this report has a limited number of data points covering the EAL area, it proposes a conceptual model for groundwater movement in the region and details the available groundwater resources.

Along with the above detailed reports, WESTON reviewed a series of unpublished well logs and related construction documents for the Southwest Water Pollution Control Plant and the Philadelphia International Airport. These data provided the framework for the development of this current study.

2.2 CURRENT INVESTIGATIONS

As part of the planning requirements for the construction of a fourth runway (Runway 8-26) at the Philadelphia International Airport, EPA has requested that DOA conduct geohydrological and geotechnical investigations in the area of the EAL. The purpose of these investigations is to determine the following:

- Has the remedial action performed at the EAL from 1979 through 1985 been effective?
- Has the New Jersey Coastal Plain Sole Source Aquifer (as defined in the 26 June 1988 *Federal Register*) been affected by the EAL?

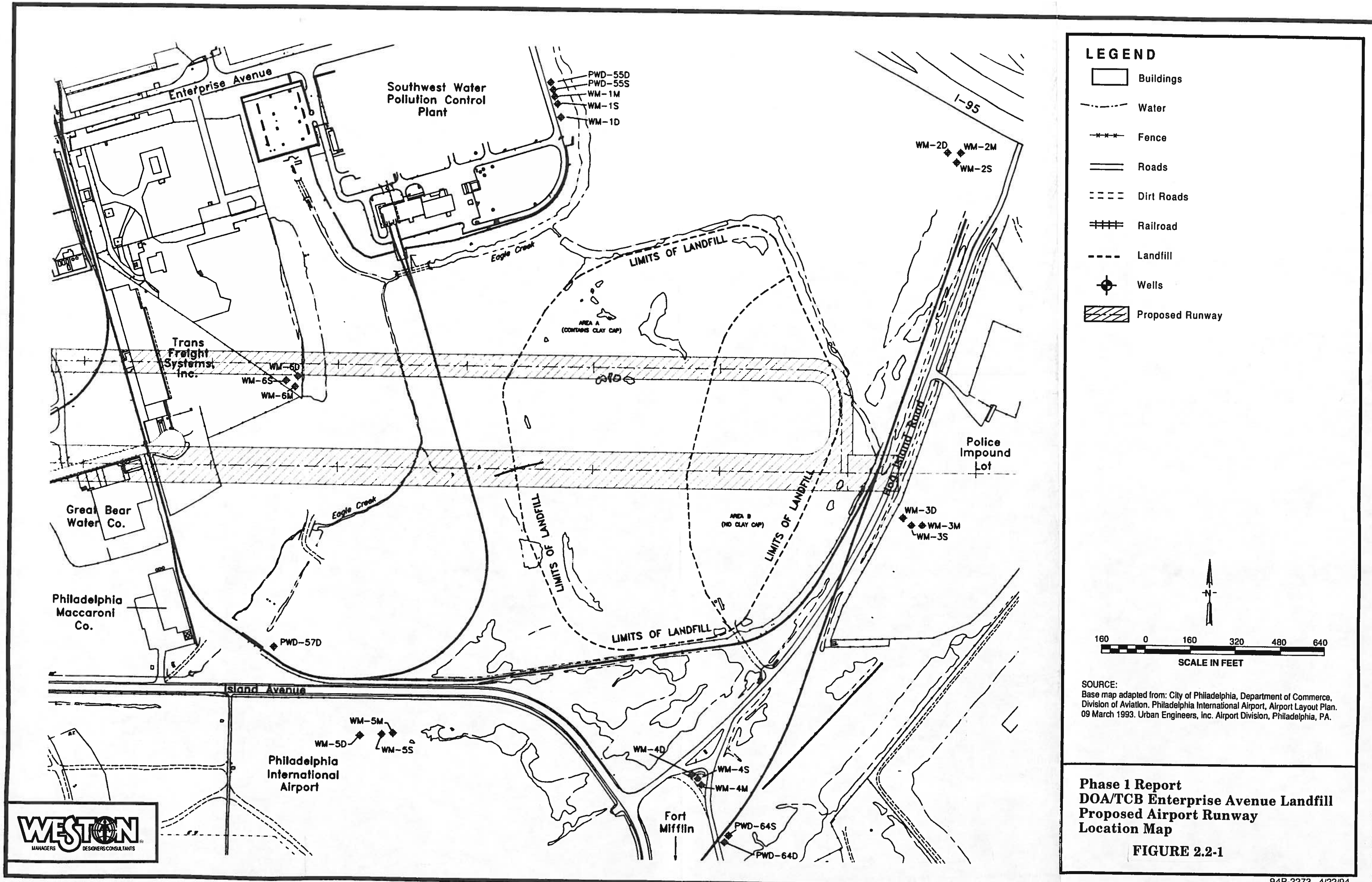
The current investigation being performed by Tuner Collie and Braden and its subcontractor WESTON is designed to answer the following questions:

- Define the lithological sequence present at the site and determine if a competent confining layer exists between the water table aquifer and the deeper sole source aquifer.
- Define the relative horizontal and vertical movement of groundwater in the various aquifers present under the site. Determine the effect (if any) of tidal fluctuations on the various aquifer systems.
- Determine the quality of the groundwater present in each of the aquifer systems underlying the site.

The investigatory methods being employed for this study are detailed in the approved WESTON work plan, provided in Appendix A. Figure 2.2-1 shows the proposed runway and its relationship to the EAL and the various features of the site.

2.3 SUMMARY

- A series of historical reports and maps describing the geology and hydrogeology in the vicinity of the EAL has been prepared.
- The current hydrogeological study is being conducted in accordance with an EPA-approved work plan.



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Proposed Airport Runway
Location Map

FIGURE 2.2-1

SECTION 3

HYDROGEOLOGICAL SITE INVESTIGATION PROCEDURES

WESTON conducted the Phase I hydrogeological investigation of the EAL between 6 January and 28 March 1994. Completed Phase I activities included a survey of existing wells; the installation, survey, development, and sampling of 18 new monitor wells; water level data collection; geophysical logging; and the abandonment of one of the existing wells.

Phase I activities were completed according to the procedures presented in WESTON's 1994 <u>Amendment No. 2 - Final Work Plan for Hydrogeological and Geotechnical Investigation at Enterprise Avenue Landfill.</u> A copy of Amendment No. 2 is presented in Appendix A. A brief summary of each of the tasks undertaken during Phase I activities is presented below. Exceptions to the procedures detailed in Amendment No. 2 are noted in the summaries below.

3.1 <u>EXISTING WELL SURVEY</u>

An existing well survey was performed by WESTON personnel on 6 January 1994. An effort was made to locate all nine of the wells installed in 1979; however, only five existing wells were found. These five wells were examined following the procedures presented in Amendment No. 2. Data were recorded on well survey forms and tabulated for presentation in Appendix B. An example of the well survey form used in the field is also included in Appendix B.

WESTON was not able to perform bailer tests of light and dense non-aqueous phase liquid layers at location PWD-57D (see Figure 3.3-1) because of its small (0.75-inch I.D.) well diameter. Sample collection tubing previously left in well PWD-57D was removed from the well, and the liquid remaining in it was examined for sheen or product. Four of the five existing wells were secured with padlocks after the well survey. The well cover at location PWD-64D could not accommodate a standard locking device and was secured using a set screw.

3.2 LANDFILL COVER INTEGRITY SURVEY

This winter's excessive snow coverage required the postponement of the continuation of the October 1993 existing landfill cover examination. WESTON will complete the landfill cover integrity survey in the Spring of 1994. Survey results will be presented in the second Phase I report scheduled for production in June 1994.

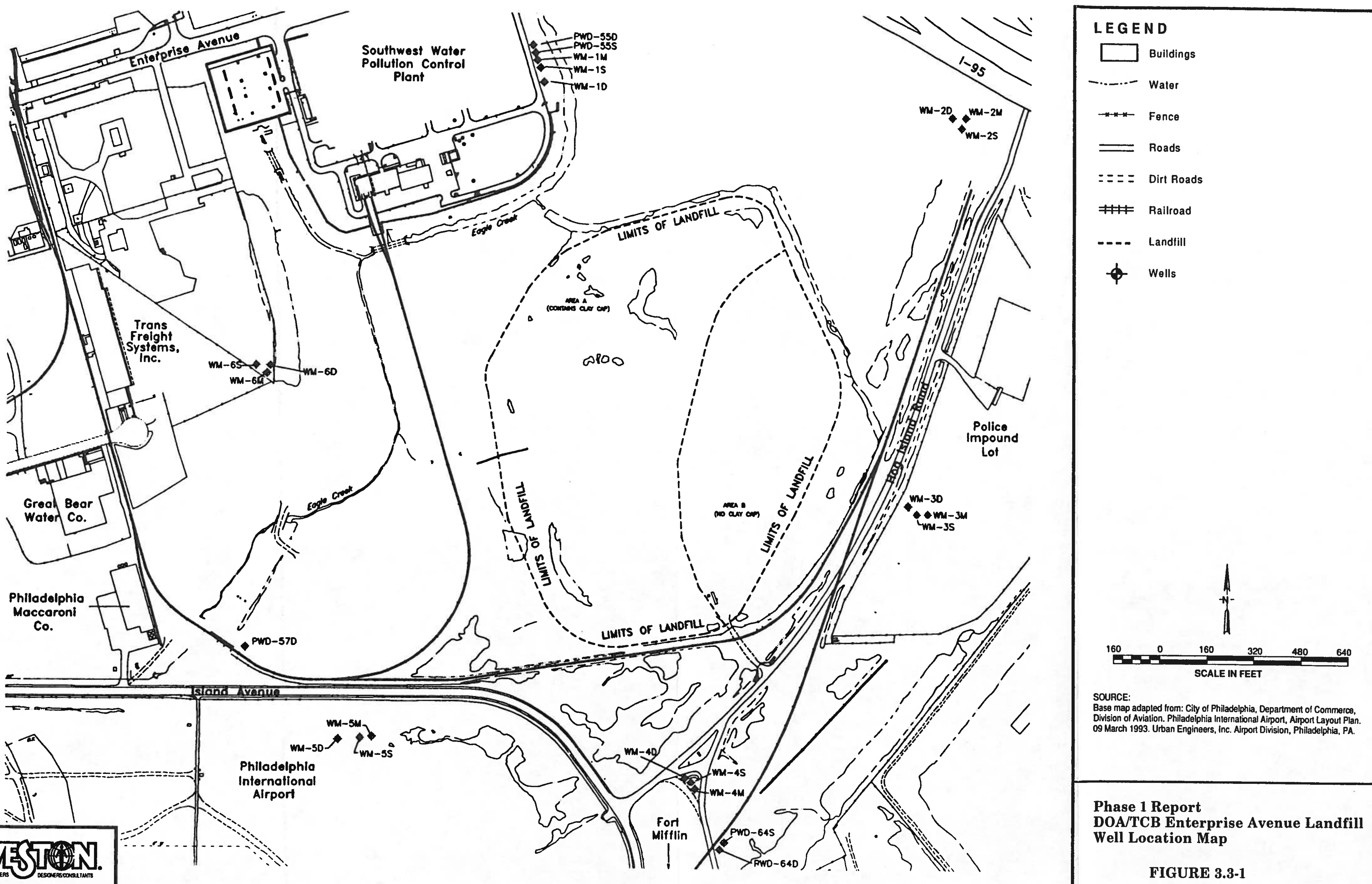
3.3 WELL DRILLING AND INSTALLATION

Phase I well drilling and installation activities were conducted between 18 January and 28 February 1994. WESTON personnel oversaw the installation of six well triplets at the locations shown in Figure 3.3-1. Well locations are identified with the prefix WM, followed by the area designation 1 through 6 and a letter indicating shallow (S), intermediate (M), or deep (D). The six triplet locations surround the EAL.

Each triplet includes a shallow well screened in near surface Recent Age river deposits, if present; an intermediate well screened in underlying Pleistocene Age sands and gravels; and a deep well screened in the first hydrologically isolated Cretaceous Age sand and gravel layer. A detailed discussion of these wells and their hydrogeologic setting is presented in Sections 4 and 5 of this report. A brief description of well installation techniques used during this investigation is provided in the following subsections.

3.3.1 Intermediate and Shallow Wells

Intermediate and shallow wells were drilled utilizing a CME-75 drill rig. Cuttings generated during drilling were spread on the ground surface in the vicinity of each borehole. A pilot boring was advanced at all intermediate well locations using 6-inch outer diameter (OD) hollow stem augers and continuous split-spoon sampling techniques. Split-spoon samples were screened for the presence of volatile organics using an organic vapor monitor (OVM) and representative lithologic samples were retained for documentation purposes.



SOURCE:
Base map adapted from: City of Philadelphia, Department of Commerce, Division of Aviation. Philadelphia International Airport, Airport Layout Plan. 09 March 1993. Urban Engineers, Inc. Airport Division, Philadelphia, PA.

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Well Location Map

FIGURE 3.3-1

94P-2274 4/22/94

Intermediate well pilot boreholes were advanced to depths ranging from 44 feet below ground surface (bgs) at WM-1M to 66 feet bgs at WM-4M. The original pilot boring for WM-6M was abandoned because of a property access issue and the abandoned boring was renamed WM-6M(A). A second attempted location was later determined to be within the footprint of the proposed runway and was consequently abandoned as WM-6M(A2). WM-6M was drilled at a location approximately 75 feet away from WM-6M(A2).

After completion of each of the pilot holes, the intermediate well pilot boreholes were reamed to depths ranging from 41 to 4 feet bgs using 8-inch OD hollow stem augers. During reaming, the lead auger was fitted with a non-treated wood plug to limit well installation problems associated with running sands.

The lithologic information obtained from drilling an intermediate well was used to determine the appropriate completion depth for the adjacent shallow well. Shallow well boreholes were reamed to depths ranging from 15 to 30 feet bgs using appropriately cleaned 8-inch OD hollow stem augers.

Shallow and intermediate wells were constructed according to the specifications presented in Amendment No. 2. The total depths of shallow and intermediate wells range from 15 feet bgs (WM-1S) to 30 feet bgs (WM-3S) and 39.7 feet bgs (WM-1M) to 54 feet bgs (WM-4M), respectively. Construction of the six shallow and six intermediate wells included the installation of a 2.5- to 2.7-foot-long sump and a 9-foot-long 0.010-inch slotted screen section. The only exception to these specifications was at locations WM-1S and WM-2M where extended sumps were not used, and the screen lengths were 5 feet and 8 feet, respectively, to accommodate local stratigraphic conditions Top to bottom screen intervals ranged from 8.5 to 27.5 feet bgs for shallow wells and 28 to 51.5 feet bgs for intermediate wells. A silica sand pack was used to backfill the annular space to a level between 2 to 3.5 feet bgs above the top of the well screen. Sand size #00 or #0 was used in shallow well construction and #1 was used for intermediate wells. A 3 to 4.5-foot-thick bentonite pellet seal was set above the sand pack. An appropriate amount of time was allowed for pellet hydration before a neat cement grout was tremied from the top of the bentonite seal to ground surface.

During initial installation of intermediate wells at locations WM-2 and WM-3, a bridging problem developed, which made continuation in the same borehole impossible. At each location, the drill rig was moved 10 feet from the original location, and the well was constructed accordingly.

3.3.2 Deep Wells

Deep wells, designed to be completed in the sole source aquifer, were drilled utilizing a Mobile B-80 drill rig. Cuttings generated during drilling were spread on the ground surface, but drill mud was containerized for later disposal. Drilling was started using air rotary techniques at location WM-3D. Drill operations were halted when borehole collapse became a problem and threatened downhole tool retrieval. WESTON and the drilling company supervisor agreed that mud rotary techniques represented the best option for borehole continuation. WESTON consulted the EPA project supervising hydrogeologist before implementing the necessary change in drill methods.

Split-spoon samples were typically collected every 5 feet, beginning at the total depth of the associated intermediate well's pilot boring, and additionally when the drilling supervisor noted a possible stratigraphic contact based on rig behavior. Split-spoon samples were screened with an OVM, and representative lithologic samples were retained. One Shelby tube was collected at two different locations (WM-2D and WM-5D) for possible future geotechnical analysis. Because additional lithologic information was needed to determine proper outer casing and/or well screen settings, WM-1D(A), SB-4D, and WM-6D(A) were completed as stratigraphic borings with total depths of 157 feet, 149 feet, and 112 feet bgs, respectively.

A loss of drill mud problem developed at WM-2D, WM-3D, and WM-6D in the surficial fill layer. This problem was resolved through the temporary installation of short lengths of

12.25-inch I.D. low carbon steel casing placed at respective depths of 14 feet, 10 feet, and 7 feet bgs.

A 12.0 or 12.25-inch diameter drill bit was used to complete deep boreholes to a depth between 2 to 9 feet into the first significant Cretaceous clay layer. The installation of 8-inch OD low carbon steel casing to depths ranging from 55 feet bgs (WM-2D) to 116.5 feet bgs (WM-5D) was completed according to Amendment No. 2 procedures. A neat cement was pressure grouted into the annulus of the outer casing and allowed to cure for a period exceeding 12 hours. The borehole was then advanced inside the 8-inch outer casing using fluid rotary techniques. Only potable water was used as the deep wells were advanced to depths ranging from 117.5 to 143 feet bgs. A 2 to 7-foot overdrilling zone was generally allowed to address a sand-running problem.

Deep well total depths ranged from 114 feet bgs (WM-2D and WM-6D) to 140.2 feet bgs (WM-5D). Deep wells were constructed in accordance with the specifications presented in Amendment No. 2. Construction of the six deep wells included a 2.5 to 3.37-foot-long sump and a 9-foot-long 0.010-inch slotted screen section. Top to bottom screen intervals ranged from 101.73 feet to 137.60 feet bgs in the deep wells. A silica sand pack, #1 size, was used to backfill the annular space to a level between 2.13 to 7.4 feet bgs above the top of the well screen. A 3- to 4-foot thick bentonite pellet seal was set above the sand pack. Final grouting procedures were the same as those used in the shallow and intermediate well installations.

All wells were completed with the installation of a 6-inch ID steel protective casing equipped with a locking device, the construction of a concrete pad, and the placement of four concrete-filled steel bollards around each well to protect against damage by vehicles.

3.3.3 Drilling and Well Installation Decontamination

All drill rigs and tools were initially decontaminated at the start of the Phase I drill effort using standard steam cleaning procedures. Rig decontamination occurred prior to moving to a new drilling location. Downhole drilling tools were decontaminated between every borehole and after deep well casing installation and flushing, prior to borehole advancement to screened depth below the confining unit.

3.3.4 Well Survey

The 18 Phase I wells and four of the five existing wells were surveyed on 9 March 1994 by a Pennsylvania Registered Land Surveyor from Chilton Engineering. Inner casing elevations were collected at all locations except PWD-55S and PWD-64S. At these two locations, outer casing elevations were collected. Because of well PWD-57D's unusual construction, it was scheduled for abandonment and therefore not surveyed. Survey data are summarized in Appendix C.

3.4 WELL DEVELOPMENT

Wells installed at the site were developed between 1 February and 1 March 1994 according to procedures outlined in Amendment No. 2. Development methods include surging and/or bailing or overpumping. Well development data are summarized in Appendix D. Purge water collected during development was containerized for later disposal.

3.5 WELL SAMPLING

The Phase I monitor well sampling round was conducted between 2 and 9 March 1994. Groundwater samples were collected from 22 wells (18 newly installed wells plus existing well pairs PWD-55S/D and PWD-64S/D) and analyzed for the following parameters:

- Target Compound List (TCL) Organics
  - Volatile Organic Compounds (VOC)
  - Base Neutral Acids (BNA)
  - Pesticides
  - Polychlorinated biphenyls (PCB)
- Total Analyte List (TAL) Metals

- Cyanide
- Total Dissolved Solids

A list of the TCL and TAL compounds is provided in Appendix E.

WESTON followed the low-flow purging and sampling methods identified in Amendment No. 2. As per specifications, a 0.2- to 0.5-liter per minute (lpm) flow rate was attempted at each well location; however, rates up to 1.1 lpm were sometimes necessary to overcome pressure head gradients.

Purging was performed using an appropriately cleaned 2-inch Grundfos RediFlo pump controlled by a converter box, which was powered by a compatible generator. Water quality parameters were collected throughout the purging process using an inline flow-through cell equipped with temperature, specific conductivity, pH, and Eh instrumentation. Additional dissolved oxygen and turbidity readings were taken using separate field instruments. Groundwater samples were collected after water quality parameters stabilized. A Phase I groundwater sampling summary, which includes stabilized field measurements at the end of low-flow purging, is presented in Appendix F. Wells WM-1S and PWD-64S went dry, unavoidably, within a five-minute purge time and were sampled after recharge.

Groundwater sampling instruments were calibrated every morning, and the calibration readings were recorded in a field logbook. Prior to use and between sampling locations, all non-dedicated sampling equipment was decontaminated according to Amendment No. 2 procedures.

Groundwater samples were collected in laboratory containers prepared in accordance with EPA protocols. The type of sample container, volume required for analysis, and any required preservatives are shown, according to specific analytical parameter, in Table 3.5-1. Table 3.5-2 provides sample collection data and identifies laboratory quality assurance and quality control (QA/QC) samples including trip blanks, field blanks, duplicates, and matrix spike (MS) and matrix spike duplicate (MSD) blanks. The frequency of QA/QC sample

Table 3.5-1

Enterprise Avenue Landfill
Groundwater Sample Container Summary

Analytical Parameter	Container Type	Chemical Preservative	Required Volume For Analysis
TCL Volatile Organic Compounds	Clear Glass/ 40mL	Hydrochloric Acid (HCL)	4 x 40mL
TCL Base Neutral Acids	Amber Glass/ 950mL	None	2 x 950mL
TCL Pesticides and Polychlorinated biphenols	Amber Glass/ 950mL	None	2 x 950mL
TAL Metals	Plastic / 1L	Nitric Acid (HNO3)	1 x 1L
Cyanide	Plastic / 1L	Sodium Hydroxide (NaOH)	1 x 1L
Total Dissolved Solids	Plastic/ 250mL	None	1 x 250mL

TCL – Target Compound List
TAL – Total Analyte List

Table 3.5–2

Enterprise Avenue Landfill
Groundwater Sample Collection and Laboratory
Quality Assurance and Quality Control Summary

Laboratory Batch Number	Well ID	Identification	Date	Time	Sample Type	Analytical Parameter: TCL VOC	TCL BNA	TCL P/PCB	TAL Metals	CN	TDS
9403L744	WM–1S	GW–WM–1S	02–Mar–94	1840	Routine	X	X	X	X	X	X
9403L744	WM–1M	GW–WM–1M	02–Mar–94	1910	Routine	X	X	X	X	X	X
9403L744	WM–1D	GW–WM–1D	03–Mar–94	1530	Routine	X	X	X	X	X	X
9403L744	WM–2S	GW–WM–2S	03–Mar–94	1230	Routine	X	X	X	X	X	X
9403L744	WM–2M	GW–WM–2M	02–Mar–94	1655	Routine	X	X	X	X	X	X
9403L744	WM–2D	GW–WM–2D	02–Mar–94	1835	Routine	X	X	X	X	X	X
9403L744	WM–2D	DP–WM–2D	02–Mar–94	1835	Duplicate	X	X	X	X	X	X
9403L744	WM–2D	FB–WM–2D	04–Mar–94	1230	Field Blank	X	X	X	X	X	X
9403L772	WM–3S	GW–WM–3S	04–Mar–94	1615	Routine	X	X	X	X	X	X
9403L772	WM–3M	GW–WM–3M	04–Mar–94	1500	Routine	X	X	X	X	X	X
9403L772	WM–3D	GW–WM–3D	04–Mar–94	1710	Routine*	X	X	X	X	X	X
9403L744	WM–4S	GW–WM–4S	04–Mar–94	1155	Routine	X	X	X	X	X	X
9403L744	WM–4M	GW–WM–4M	03–Mar–94	1655	Routine	X	X	X	X	X	X
9403L744	WM–4D	GW–WM–4D	03–Mar–94	1755	Routine	X	X	X	X	X	X
9403L772	WM–5S	GW–WM–5S	07–Mar–94	1310	Routine	X	X	X	X	X	X
9403L772	WM–5M	GW–WM–5M	07–Mar–94	1210	Routine	X	X	X	X	X	X
9403L786	WM–5D	GW–WM–5D	08–Mar–94	1105	Routine*	X	X	X	X	X	X
9403L786	WM–5D	FB–WM–5D	08–Mar–94	1615	Field Blank	X	X	X	X	X	X
9403L772	WM–6S	GW–WM–6S	07–Mar–94	1700	Routine	X	X	X	X	X	X
9403L772	WM–6M	GW–WM–6M	07–Mar–94	1740	Routine	X	X	X	X	X	X
9403L786	WM–6D	GW–WM–6D	08–Mar–94	1250	Routine	X	X	X	X	X	X
9403L786	WM–6D	DP–WM–6D	08–Mar–94	1250	Duplicate	X	X	X	X	X	X
9403L802	PWD–55S	GW–55S	09–Mar–94	1500	Routine	X	X	X	X	X	X
9403L744	PWD–55D	GW–55D	03–Mar–94	1445	Routine	X	X	X	X	X	X
9403L802	PWD–64S	GW–64S	09–Mar–94	1140	Routine	X	X	X	X	X	X
9403L802	PWD–64D	GW–64D	09–Mar–94	1010	Routine	X	X	X	X	X	X
9403L744		TB–1	02–Mar–94		Trip Blank	X					
9403L744		TB–2	03–Mar–94		Trip Blank	X					
9403L744		TB–3	04–Mar–94		Trip Blank	X					
9403L786		Trip Blank	08–Mar–94		Trip Blank	X					
9403L802		Trip Blank	09–Mar–94		Trip Blank	X					

*Extra volume collected for matrix spike and matrix spike duplicate blanks.
TCL – Target Compound List
TAL – Total Analyte List
VOC – Volatile Organic Compounds

BNA – Base Neutral Acids
P/PCB – Pesticides and Polychlorinated biphenols
CN – Cyanide
TDS – Total Dissolved Solids

collection followed the Amendment No. 2 requirement of 1 per 20 samples, and two complete QA/QC sample sets, with the exception of trip blanks, were collected. Trip blanks were included in every shipment.

WESTON field personnel followed EPA chain-of-custody procedures to ensure the integrity of all samples. Sample packaging and shipping was completed using the methods identified in Amendment No. 2.

Methods used for the laboratory analysis of groundwater for the previously specified parameters were the full target compound list and target analyte list using the EPA Contract Laboratory Program (CLP) Superfund Analytical methods for Low Concentration Water for Organics Analysis (10/92) and Low Concentration Water for Inorganic Analysis (10/91). Sample results are discussed in Section 5 and Section 6 of this report.

3.6 WATER LEVEL DATA COLLECTION

A series of groundwater level measurements were collected at the site with an electric water level probe. Table 5.2-2 in Section 5 presents a summary of five complete water level data collection rounds, which included all of the newly installed wells and four of the five existing wells. Water level measurements for existing well PWD-57D were not taken because no vertical elevation data were available for this well.

As part of the Phase I hydrogeological investigation, WESTON conducted a long-term water level monitoring test between 15 and 28 March 1994. Electronic data loggers, in situ long term monitors (LTMs), and Hermits 1000 and 2000, were connected to pressure transducers and installed in all 18 newly installed wells and existing wells PWD-55S and PWD-55D. Water level measurements were taken at 5-minute intervals from all wells during the entire 2-week period of monitoring.

WESTON also obtained precipitation data from the National Weather Service Station located at Philadelphia International Airport. An onsite barometric probe (located at monitoring well MW-1D) was used to collect atmospheric pressure data. Delaware River tidal data were obtained from the U.S. Army Corps. of Engineers from the National Oceanic Atmospheric Administration (NOAA) Gauging Station in Philadelphia for inclusion in the hydrogeological study.

3.7 GEOPHYSICAL LOGGING METHODS

Gamma logging and electromagnetic induction logging methods were employed at the site in all of the intermediate and deep newly installed wells. The procedures employed to complete this logging are detailed in this section.

3.7.1 Gamma Logging Instrumentation and Field Procedures

A Neltronic Instruments 1 7/8-inch diameter probe was used as the downhole detector at the Enterprise Avenue site. The analog output signal from the probe is processed through a ratemeter at the surface and recorded on a conventional logging chart recorder. Output from a pulse generator is used to calibrate the signal output. The depth of the probe is synchronized to the recorder chart drive by an optical depth encoder. The logging unit is mounted in a large van and is powered by an AC generator.

Logs were generally run both down and up in each hole at a rate of approximately 15 to 18 feet per minute. The complete "down" log was used in place of a short repeat section that is customarily run to check for repeatability. A reference depth marker on the logging cable serves as control for the digital depth counter. Land surface was used as the reference point in all logs. In the deep monitoring wells, logs were recorded at a depth scale of 1 inch equals 20 feet of borehole and at a scale of 1 inch equals 10 feet of borehole. Shallow and medium holes were logged at a scale of 1 inch equals 10 feet. A horizontal scale of 1 inch equals 10 CPS was used in all cases. Instrument drift was checked at the end of each logging run by noting any change in the electrical zero point and the deflection of a calibration signal of known frequency.

3.7.2 Induction Logging Instrumentation and Field Procedures

A Robertson Geologging Limited Portalog system with a 8002-18/G combination induction/gamma ray tool was used at the Enterprise Avenue site. Both the induction and gamma ray log were recorded simultaneously, but all analyses and interpretations used the gamma logs recorded in Phase 1 of the investigation. Logs were run in existing "medium" and "deep" monitoring wells. The Portalog system produces both a paper field record and a digital data file on a diskette. The unit, including winch and electronics, operates from an automotive battery. The main transmitter and receiver coil spacings on the probe are 40 centimeters (15.6 inches), which is theoretically the depth of investigation. Readings are recorded at 0.1-foot depth intervals.

The induction portion of the tool is field-calibrated by first placing the tool in the air and recording the resulting signal. The signal has no attenuation in air, and the reading is therefore a known reference point. A calibration coil placed around the tool then provides two additional conductivity values. The three values are used to calculate a set of coefficients for a regression equation, which is then applied by the system software to each raw conductivity reading.

3.8 WELL ABANDONMENT

Existing well 57-D, adjacent to the railroad track at the macaroni factory, was abandoned. The 8-foot protective casing was removed and steam cleaned. The top of the well was cut off 1 foot bgs. The well bore was then filled with bentonite pellets for its entire length. Finally, a 2-feet by 2-feet grout cap was formed and poured over the top of the well.

3.9 SUMMARY

- Phase I activities were completed according to Amendment No. 2 procedures with the exceptions noted previously.
- Five of the nine wells installed in 1979 were located and included in the 6 January 1994 existing well survey.

- The landfill cover integrity survey will be completed in the Spring of 1994.

- Six well triplets were installed between 18 January and 28 February 1994 at locations around the EAL site. Each triplet includes a shallow well screened in near surface Recent Age river deposits, if present; an intermediate well screened in underlying Pleistocene Age sands and gravels; and a deep well screened in the first hydrologically isolated Creteaceous Age sand and gravel layer.

- Well casing elevations were surveyed on 9 March 1994 by a Pennsylvania Registered Land Surveyor.

- Wells installed during Phase I field activities were developed between 1 February and 1 March 1994.

- Groundwater samples were collected from the 18 newly installed wells plus existing well pairs PWD-55S/D and PWD-64S/D and analyzed for TCL organics, TAL metals, cyanide, and total dissolved solids.

- Five rounds of manual water level data collections were completed using an electric water level probe.

- Long-term water level monitoring using electronic data loggers was conducted between 15 and 28 March 1994 as part of the Phase I hydrogeological investigation. Precipitation and Delaware River tidal data was obtained for use in this investigation.

- Gamma logging and electromagnetic induction logging methods were employed at the site in all of the newly installed intermediate and deep wells.

SECTION 4
GEOLOGY

4.1 PHYSIOGRAPHIC SETTING

The area covered by this investigation lies within the Atlantic Coastal Plain physiographic province as described by Fenneman (1938, p.1). The inner or landward margin of the Atlantic Coastal Plain is called the Fall Line, which is identified topographically by an abrupt transition from the rolling hills of the Piedmont to the flat lowlands of the Atlantic Coastal Plain.

The topographic differences between these two regions reflect the differences in the composition and structure of the rock materials underlying their surfaces. The Piedmont is underlain by dense, hard, crystalline rocks that offer considerable resistance to erosion and support an uneven hilly surface, which stands well above the general level of the adjacent Atlantic Coastal Plain. The Atlantic Coastal Plain is underlain by soft unconsolidated deposits that yield readily to the processes of erosion and form low, nearly flat plains and a broad, shallow valley.

The EAL site lies wholly within the Atlantic Coastal Plain Physiographic Province. Within the area of this investigation, the land surface has a gentle slope from the Fall Line southeast to the Delaware River. The general level of the land surface rises from sea level along the river to about 40 feet above mean sea level (MSL) at the Fall Line. The uniformity of the surface is interrupted locally by features of the present cycle of erosion.

4.2 REGIONAL GEOLOGY

Philadelphia is underlain by crystalline rocks and by the younger unconsolidated sediments of the Coastal Plain. The crystalline rocks, chiefly of the Wissahickon Formation of Late Proterozoic and early Paleozoic age, crop out in the Piedmont, and their surface slopes southeastward, forming the basement beneath the Coastal Plain sediments. The deepest

Coastal Plain sediments in ascending order are the Potomac Group and Raritan and Magothy Formations of Cretaceous Age, which form the Potomac-Raritan-Magothy aquifer system. This aquifer system has been subdivided into the following units: lower sand, low clay, middle sand, middle clay, upper sand, and upper clay. Generally, the Cretaceous sediments are overlain by Pleistocene sediments, chiefly the informally named "Trenton gravel" (as used by Owens and Minard, 1979), which in turn may be veneered by fine-grained Holocene sediments.

The Wissahickon Formation consists chiefly of schist that is believed to represent a thick accumulation of arkosic and argillaceous sediments that were metamorphosed into dense, hard foliated rock. These rocks typically exhibit well-developed cleavage and jointing.

The configuration of the erosion surface on the crystalline bedrock beneath the Coastal Plain sediments is that of a southeast-dipping surface channelled by the ancestral Schuylkill and Delaware Rivers. These ancient valleys are important because they contain thick accumulations of sediments of Cretaceous Age, which comprise the productive sources of groundwater in the area.

The ancestral Schuylkill River is represented by four south to southeast-trending channels carved in the crystalline rock floor beneath south Philadelphia. These are, from south to north, the Point Breeze, League Island, Greenwich Point, and Washington Square troughs. The EAL site lies in the axis of the Point Breeze trough. A bedrock surface map for this part of Philadelphia shows the presence of a bedrock high east of the site (Greenman et al., 1961). Logs obtained by WESTON from the Pennsylvania Department of Transportation confirm the presence of this bedrock high, which separates the Point Breeze and the League Island troughs.

The sand and gravel layers of the Cretaceous PRM aquifer system generally consist of coarse to medium sands and gravels. In the PRM, up to three distinct sand and gravel layers are reported to exist in the Philadelphia area. These sand and gravel layers are interbedded with layers of clay and silt, which form a series of confining units between the sand and gravel units. In the Philadelphia area, up to three clay and silt-containing units are reported to be present in the PRM.

The Pleistocene sediments (Trenton gravel) consist of sand and gravel and minor amounts of clay. These sediments attain a maximum thickness of about 80 feet in this region; the typical thickness, however, is about 40 feet (Greenman et al., 1961, p.44).

The Holocene sediments are composed of mud, silt, and fine sand. These sediments are nearly 80 feet thick in some parts of south Philadelphia near the Delaware and Schuylkill Rivers, but elsewhere the thickness rarely exceeds 28 feet and is usually less than 10 feet (Greenman et al., 1961, p.48).

In addition to the above mentioned naturally occurring sediments, manmade fill has been placed in various locations in the region. Thicknesses of this fill layer are highly variable.

4.3 SITE-SPECIFIC GEOLOGY

The geologic interpretation of the area around EAL is based on lithologic and geophysical data collected from the six well triplets installed during Phase I activities. The stratigraphic sequence encountered at EAL is divided into four major overburden units:

1. Fill Material.
2. Quarternary Age alluvium (Qal).
3. Pleistocene Age sands and gravels (Qp).
4. Cretaceous Age interbedded sands and gravels with silts and clays of the PRM Formation (Kprm).

Each of these units is described in detail below.

4.3.1 Fill Material

A manmade fill layer is present at each of the well locations. The fill material composition varies from one location to another. The 13.5-foot-thick fill layer at WM-1 is a yellow brown fine sand, reportedly New Jersey select fill. At well locations WM-2 and WM-3, the silty sand fill material includes brick and rock fragments, wood, glass, plastic and metal pieces, and ash. At these two locations, the recorded thicknesses are 10 feet and 9 feet, respectively. A 4-foot-thick construction rubble and yellow brown gravelly silty sand fill exists at WM-4. At WM-5, the fill material is a dark gray silty sand with gravel and is 6 feet thick. A 15.7-foot-thick layer of black ash fill is present at well location WM-6. The thickness of the fill layer decreases south of the EAL site toward well locations WM-4 and WM-5.

4.3.2 Quaternary Age Alluvium (Qal)

Naturally deposited Qal underlies the fill layer at all EAL Phase I drill locations except WM-1. At this location, the Qal was reportedly removed during construction activities at the Southwest Water Pollution Control Plant in the early 1980s. The Qal is generally characterized as a dark-gray, organic, rich, fine, sandy clay and silt which has low to moderate plasticity. Where present at the site, the thickness of the Qal ranges from 14.3 feet (WM-6 area) to 24.9 feet (WM-2 area). A shallow water table develops in the Qal at a depth of 6 to 8 feet bgs.

4.3.3 Pleistocene Age Sands and Gravels (Qp)

The Qp unit underlies the Qal. At EAL, the Qp is typically a poorly sorted, non-cohesive, brown to dark-gray silty sand and gravel layer. During drilling, this permeable unit was found to be saturated. The approximate thickness of the Qp ranges from 11.1 feet at WM-2 to 62.4 feet at WM-4. The unit appears to thin in a northern direction.

4.3.4 Cretaceous Age Potomac-Raritan-Magothy Formation (Kprm)

The Pleistocene Age sediments overlie the Cretaceous Age Kprm sequence. This stratigraphic sequence consists of alternating layers of silts and clays with low permeability and sands and gravels that are much more permeable. A description of the six Kprm layers, based on lithologic data encountered at the EAL site, follows and is presented in a shallow to deep order.

Layer 1: Layer 1 typically consists of a cohesive yellow clayey silt. Layer 1 is believed to be discontinuous in the EAL area and was not encountered at locations WM-2 and WM-4. Layer 1 is present at all other Phase I locations at thicknesses generally ranging from 1.3 to 4 feet. However, at WM-1, a thickness of 11.5 feet was recorded.

Layer 2: Layer 2 is generally classified as a yellow or brown sand with gravel. Variable grain size was noted. This layer was not encountered at WM-2 or WM-4. At the other four well locations, the approximate thickness of this layer ranges from 16.5 feet (WM-5) to 21.7 feet (WM-3).

Layer 3: At most locations, Layer 3 classifies as a stiff, cohesive low permeability red silt and clay. Other colors noted include white, brown, and yellow. Composition differs slightly to include percentages of fine sand at locations WM-4, WM-5, and WM-6. Layer 3 is believed to have a more continuous areal extent than Layer 1. Layer 3 is only 4.5 feet thick at WM-5, but at each of the other five well locations the thickness ranges from 24 feet (WM-4) to 51 feet (WM-2). The thickness of this silt and clay layer appears to decrease to the south of the EAL site.

Layer 4: The composition of Layer 4 changes with depth, but most often coarsens downward from a sand to a sand and gravel. White, brown, yellow, and gray colors are found in this layer. The thickness of Layer 4 ranges from 16.5 feet at WM-1 to greater than 35 feet at WM-4. During Phase I drilling activities, penetration of this layer occurred only at locations WM-1 and WM-5.

Layer 5: At WM-1 and WM-5, Layer 5 is represented as a red and/or gray clay and silt. The thickness ranges from 5 feet at WM-1 to 12 feet at WM-5.

Layer 6: Layer 6 is a sand and gravel layer whose composition varies with location and depth. This layer was not fully penetrated during Phase I drilling efforts at locations WM-1 and WM-5; therefore, total layer thickness data are not available. Layer 6 is greater than 23 feet thick at well location WM-1.

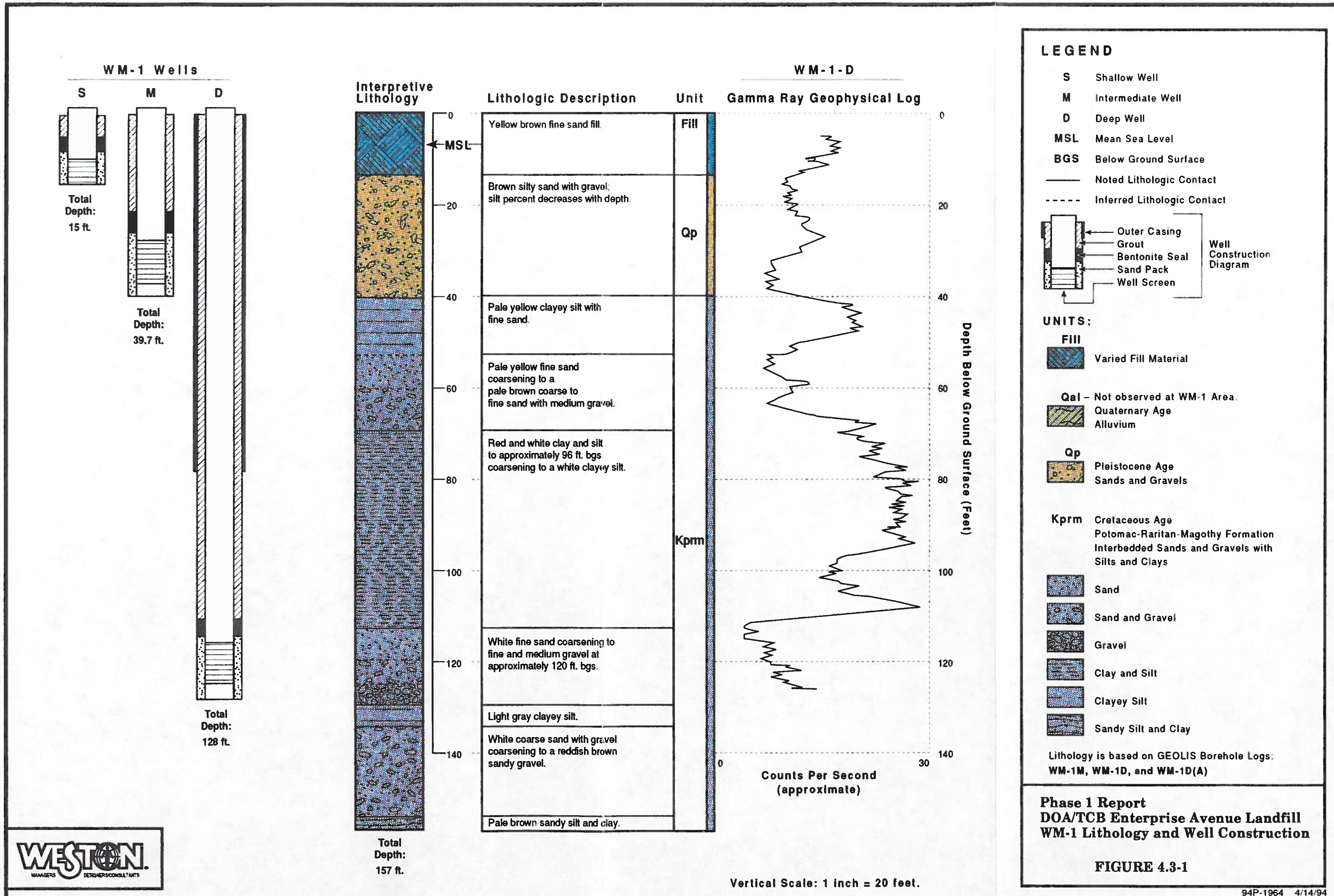
The stratigraphic sequence observed at each of the six well locations surrounding the EAL is visually presented in Figures 4.3-1 through 4.3-6. Each figure represents a composite of one Phase I well drilling location and includes a lithologic interpretation and description, a gamma ray geophysical log, and a well construction diagram for each well (shallow, intermediate, and deep) triplet. The interpretive lithology and lithologic description are based on the more detailed GEOLIS$_{TM}$ borehole logs presented in Appendix G. Field notes and information provided during borehole drilling and GEOLIS logging were used to note lithologic contacts (see legends on Figures 4.3-1 through 4.3-6, solid line usage). Poor split-spoon recovery at certain intervals required that lithologic contacts be inferred (see legends on Figures 4.3-1 through 4.3-6, dashed line usage).

Table 4.3-1 shows top of unit depths and unit thicknesses encountered during this investigation. The information provided in this table was the basis for unit contacts in Figures 4.3-1 through 4.3-6 and was generated from the GEOLIS borehole logs.

4.4 GEOPHYSICAL LOGGING

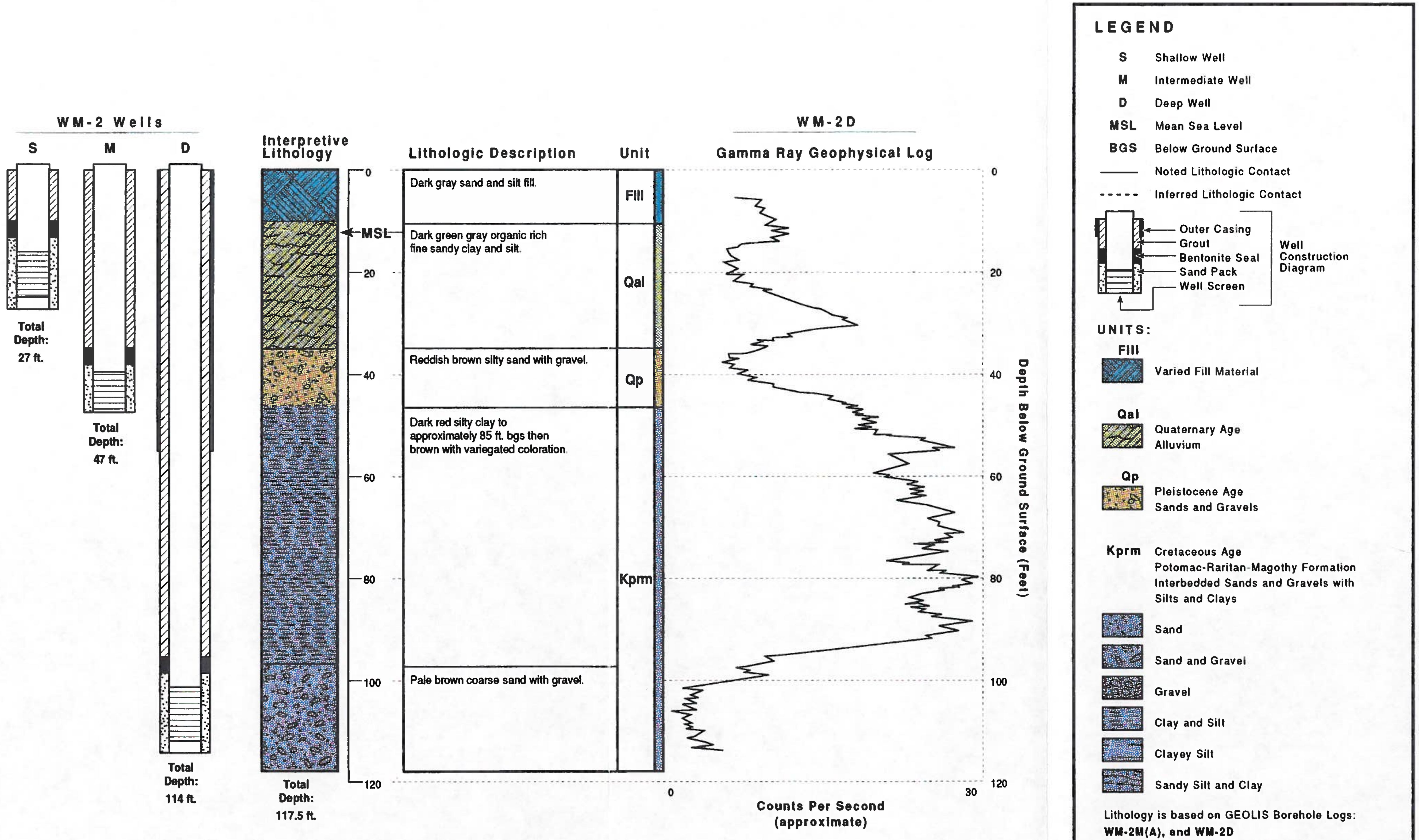
4.4.1 Purpose

Borehole logging techniques measure the properties of 1) the formation penetrated by the borehole, 2) fluids in the borehole or formation, or 3) the borehole construction. Sensors located on a downhole probe convert physical parameters of the surrounding environment to electrical signals, which are then plotted as a function of depth. Probes are lowered down the borehole on a cable that provides both the electrical connection to the surface and the necessary mechanical strength.



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
WM-1 Lithology and Well Construction

FIGURE 4.3-1

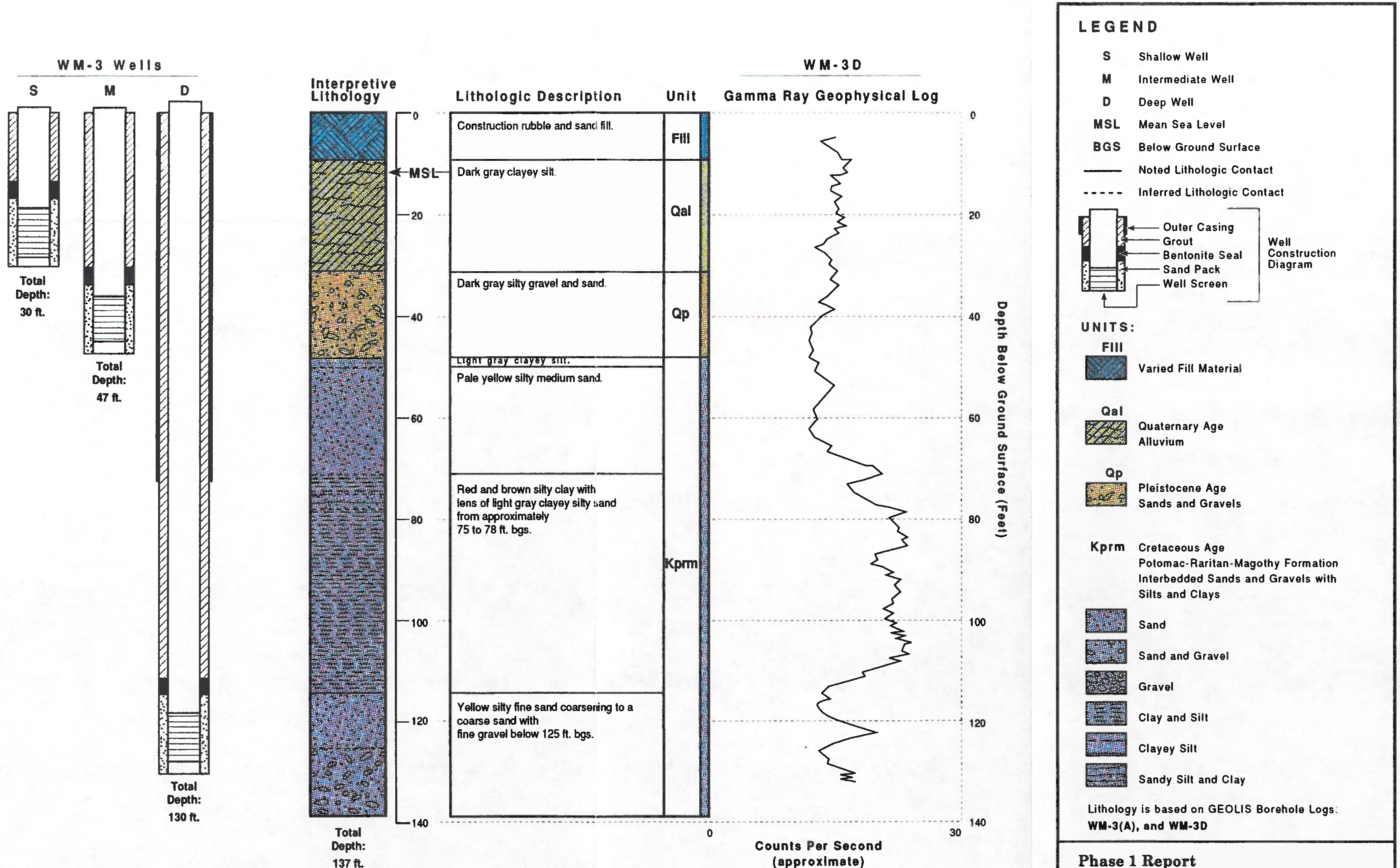


WESTON MANAGERS DESIGNERS/CONSULTANTS

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
WM-2 Lithology and Well Construction

FIGURE 4.3-2

94P-1965 4/12/94

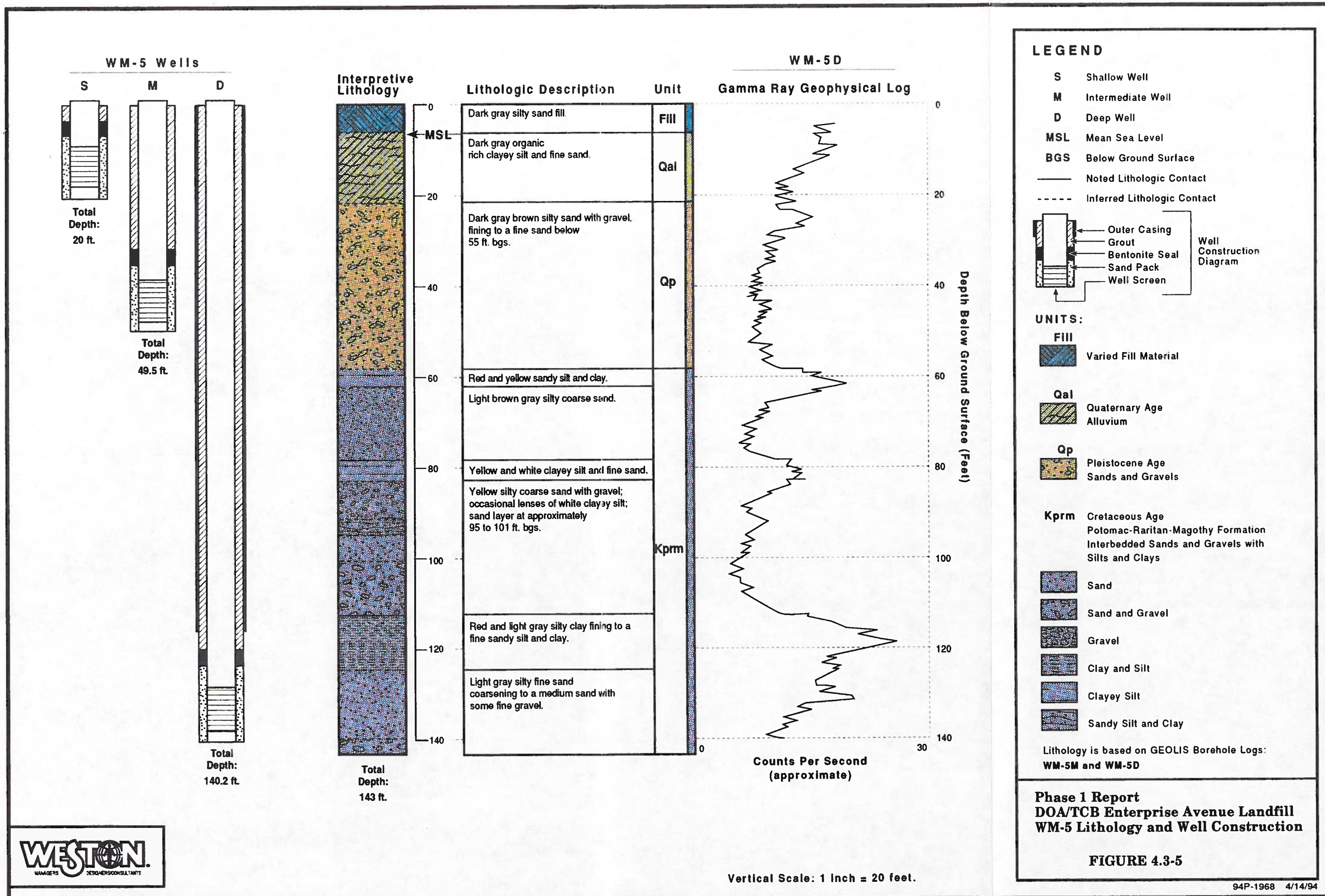


Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
WM-3 Lithology and Well Construction

FIGURE 4.3-3

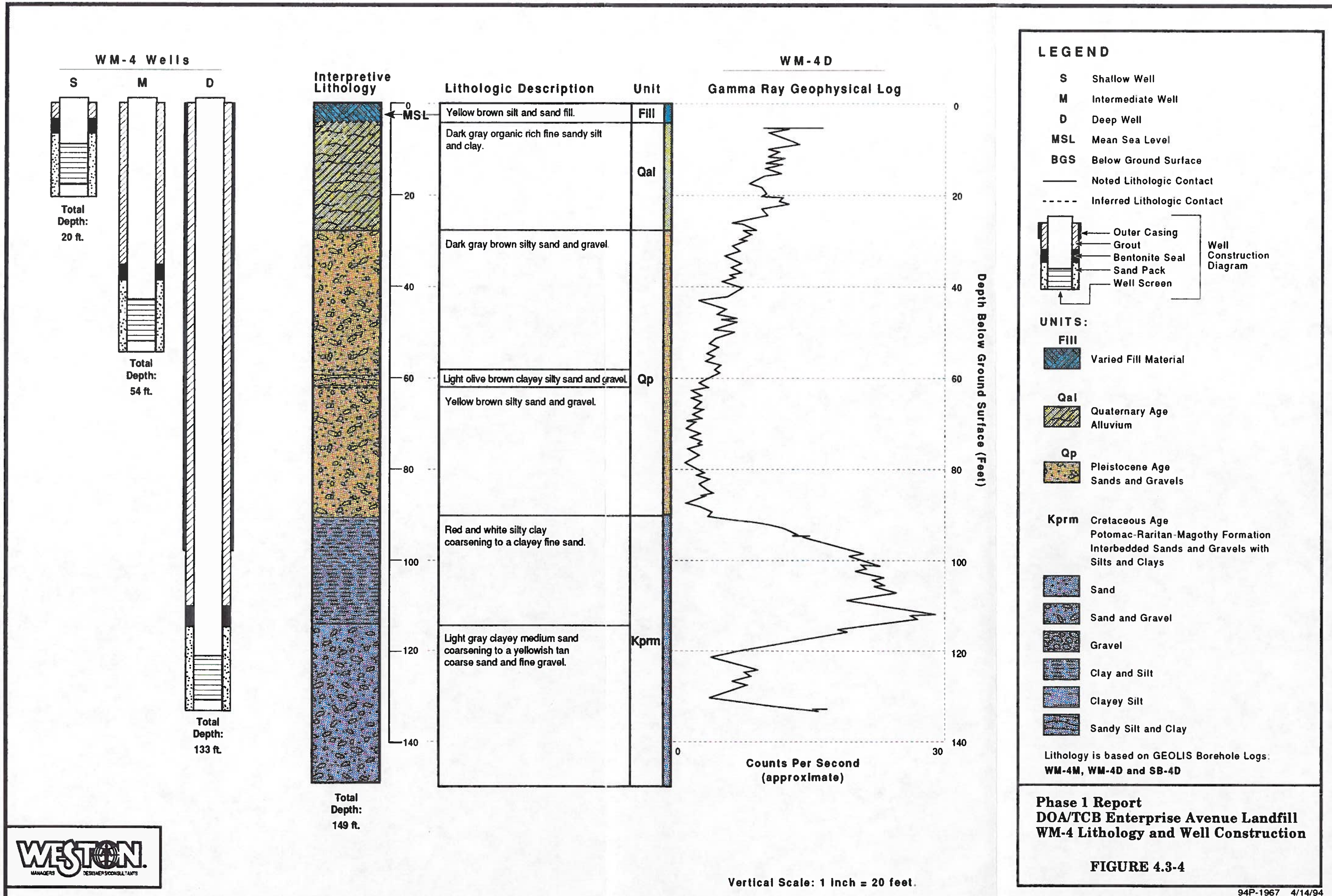
94P-1966 4/14/94

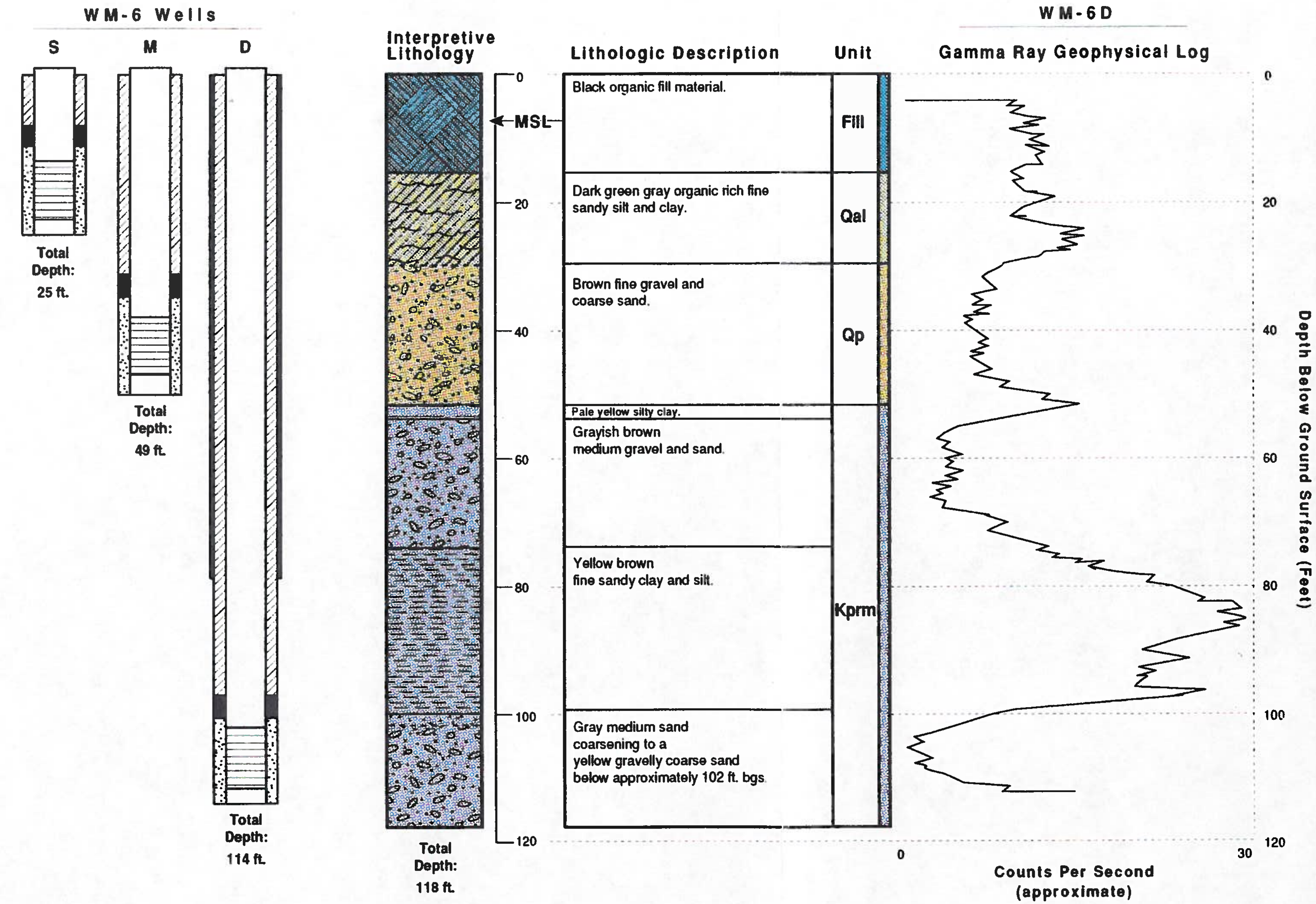
WESTON MANAGERS DESIGNERS/CONSULTANTS



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
WM-5 Lithology and Well Construction

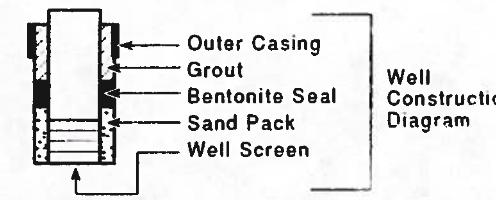
FIGURE 4.3-5


WM-4 Wells
S
M
D
Total Depth: 20 ft.
Total Depth: 54 ft.
Total Depth: 133 ft.
Interpretive Lithology
Total Depth: 149 ft.
MSL
Lithologic Description
Unit
Yellow brown silt and sand fill.
Fill
Dark gray organic rich fine sandy silt and clay.
Qal
Dark gray brown silty sand and gravel.
Light olive brown clayey silty sand and gravel.
Qp
Yellow brown silty sand and gravel.
Red and white silty clay coarsening to a clayey fine sand.
Light gray clayey medium sand coarsening to a yellowish tan coarse sand and fine gravel.
Kprm
WM-4D
Gamma Ray Geophysical Log
Counts Per Second (approximate)
Depth Below Ground Surface (Feet)
Vertical Scale: 1 inch = 20 feet.
LEGEND
S Shallow Well
M Intermediate Well
D Deep Well
MSL Mean Sea Level
BGS Below Ground Surface
Noted Lithologic Contact
Inferred Lithologic Contact
Outer Casing
Grout
Bentonite Seal
Sand Pack
Well Screen
Well Construction Diagram
UNITS:
Fill Varied Fill Material
Qal Quaternary Age Alluvium
Qp Pleistocene Age Sands and Gravels
Kprm Cretaceous Age Potomac-Raritan-Magothy Formation Interbedded Sands and Gravels with Silts and Clays
Sand
Sand and Gravel
Gravel
Clay and Silt
Clayey Silt
Sandy Silt and Clay
Lithology is based on GEOLIS Borehole Logs: WM-4M, WM-4D and SB-4D
Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
WM-4 Lithology and Well Construction
FIGURE 4.3-4
94P-1967 4/14/94



LEGEND

S	Shallow Well
M	Intermediate Well
D	Deep Well
MSL	Mean Sea Level
BGS	Below Ground Surface
———	Noted Lithologic Contact
- - - -	Inferred Lithologic Contact



UNITS:

Fill
- Varied Fill Material

Qal
- Quaternary Age Alluvium

Qp
- Pleistocene Age Sands and Gravels

Kprm
- Cretaceous Age Potomac-Raritan-Magothy Formation Interbedded Sands and Gravels with Silts and Clays
- Sand
- Sand and Gravel
- Gravel
- Clay and Silt
- Clayey Silt
- Sandy Silt and Clay

Lithology is based on GEOLIS Borehole Logs: WM-6M(A2), WM-6D, and WM-6D(A)

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
WM-6 Lithology and Well Construction

FIGURE 4.3-6

WESTON MANAGERS DESIGNERS/CONSULTANTS

94P-1969 4/14/94

Table 4.3-1

Enterprise Avenue Landfill
Geolis Borehole Log based Lithologic Table

Well Location	Depth to Top of Unit (FT/BGS)									Total Depth of Borehole (FT/BGS)
				Kprm (over– to underlying sequence)						
	Fill	Qal	Qp	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	
WM-1	0	--	13.5	40.5	52.0	69.0	112.5	129.0	134.0	157.0
WM-2	0	10.0	34.9			46.0	97.0			117.5
WM-3	0	9.0	30.9	48.0	49.3	71.0	114.0			137.0
WM-4	0	4.0	27.6			90.0	114.0			149.0
WM-5	0	6.0	22.0	58.0	62.0	78.5	83.0	113.0	125.0	143.0
WM-6	0	15.7	30.0	51.4	53.5	74.0	100.0			118.0

Well Location	Unit Thickness (Feet)									Total Encountered Kprm (Feet)
				Kprm (over– to underlying sequence)						
	Fill	Qal	Qp	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	
WM-1	13.5		27.0	11.5	17.0	43.5	16.5	5.0	>= 23.0	116.5
WM-2	10.0	24.9	11.1			51.0	>= 20.5			71.5
WM-3	9.0	21.9	17.1	1.3	21.7	43.0	>= 23.0			89.0
WM-4	4.0	23.6	62.4			24.0	>= 35.0			59.0
WM-5	6.0	16.0	36.0	4.0	16.5	4.5	30.0	12.0	>= 18.0	85.0
WM-6	15.7	14.3	21.4	2.1	20.5	26.0	>= 18.0			66.6

FT/BGS Feet Below Ground Surface
Units:
Qal – Quarternary Age alluvium
Qp – Pleistocene Age sands and gravels
Kprm – Cretaceous Age
Potomac–Raritan–Magothy Formation
Layers 1 through 6
Note: Layers 1,3, and 5 are generally silt/clay. Layers 2,4, and 6 are generally sand and gravel.

Unless indicated unit thicknesses are less than or equal to number shown.

The most common uses of geophysical logs in site investigations are identification of lithology and correlation of geologic units. Log shapes are often diagnostic of geologic environments and may be useful in predicting lithologic trends or formation hydrogeologic properties. Geophysical logging also provides an independent check on formation sampling procedures. The goal of a proposed logging program needs to be carefully assessed against the field conditions to identify physical problems in data collection and geologic factors that may complicate data interpretations.

At the EAL site, the primary goals of the logging program were to identify aquifers and confining units and assist in the correlation of the stratigraphy. The natural gamma ray (gamma) log is particularly useful for these purposes. In addition, electromagnetic induction logging was employed to determine conductivities of formation water. The instrumentation and techniques used to perform these two types of borehole logging are discussed in Subsection 3.7.

4.4.2 Gamma Logging Theory

The gamma log measures the natural radioactivity of the material surrounding the probe. Most systems used in environmental or water well work use a scintillometer type of gamma ray detector that consists of a sodium-iodine crystal optically coupled to a photomultiplier tube. The resulting electrical signal is processed so that the final output is proportional to the rate of gamma emission. The gamma log is primarily an indicator of lithology.

Only the naturally occurring radioactive isotopes, uranium-238, thorium-232, and potassium-40, have half-lives that are long enough to be consistently useful in general logging work. Radiation from uranium and thorium exhibit a spectrum of energy levels depending on the daughter products that are present, while potassium has a single gamma energy peak. The natural gamma log measures the total radiation emitted by all three isotopes, which are usually most abundant in fine-grained sediments or granitic rock. Generally, clays or shales exhibit the highest radiation while clean sands or sandstone have the lowest radiation.

Gamma logs from major geophysical service companies are usually calibrated in American Petroleum Institute (API) units, which is an arbitrary scale related to the average radiation produced by a mid-continent shale. Other logging equipment, including that used at the EAL site, is usually calibrated in counts per second (CPS). Logs calibrated in counts per second can be quantitatively compared only to other logs run with the same system.

4.4.2.1 Gamma Log Interpretation

Interpretations were made mainly by using the logs from the six deep monitoring wells. The log validity was checked by comparing duplicate logs in the same hole and by comparing logs with cores and drill cuttings. All logs appeared to be reliable and accurate. Time-stratigraphic units were first identified from local experience after comparing the logs to formation samples. Hydrogeologic subdivisions were then identified and assigned informal designations for correlation purposes. The informal units were tentatively correlated (see Table 4.4-1) to the stratigraphic nomenclature of Greenman and others (1961). The uncertainties inherent in using their nomenclature, which is based on the stratigraphy from the Raritan Bay, NJ area are recognized. The terminology, however, is generally familiar to local geologists. A detailed regional correlation, which would be necessary for resolution of a correlation problem, is beyond the scope of the project. The stratigraphy beneath the site is a fluvial cut and fill sequence in which older deposits have been eroded and replaced with younger sediments. Correlations in this type of environment are generally difficult although experience elsewhere in the northern Atlantic Coastal Plain indicates that clays are more easily correlated than sands. This approach also seemed to be true at the EAL site.

Six major units were recognized from the geophysical logs and are listed in Table 4.4-1 along with the probable correlation to the stratigraphy of Greenman and others (1961). A detailed discussion of the units is given in the section following. Elevations on the tops and bottoms of the units as determined from the geophysical logs are given in Table 4.4-2. The individual gamma ray logs have been combined with the corresponding lithology and well construction figures and are shown in Figures 4.3-1 through 4.3-6

Table 4.4-1

Hydrostratigraphic Units at Enterprise Avenue Site

Age (System)	This Report	Greenman, et al. (1961)	Thickness (ft)	Elevation Top (MSL)	Elevation Bottom (MSL)
Quaternary	Recent (Qal) and Pleistocene (Qp)	Pleistocene Deposits	40-86	± 10	-30 to -76
Cretaceous	Upper confining unit	Upper clay member	5-10	-35 to -47	-45 to -55
	Upper confined aquifer	Old Bridge sand member	15	-45 to -55	-60 to -70
	Middle confining unit	Middle clay member	24 - 54	-34 to -88	-78 to -112
	Middle confined aquifer	Sayreville sand member	14+	-78 to -112	-104+
	Lower confining unit	Lower clay member	Unknown*	-104	Unknown*

*Bottom of unit was not penetrated.

Table 4.4-2

Hydrostratigraphic Unit Elevations from Gamma Ray Logs
Enterprise Avenue Site

Unit	Monitor Well ID	Top (ft, MSL)	Bottom (ft, MSL)	Thickness (ft)
Q	1D	+7	-33	40
UCU		-33	-43	10
UCA		-43	-61	18
MCU		-61	-103	42
MCA		-103	-117*	—
Q	2D	+10	-34	44
UCU		Not present		
UCA		Not present		
MCU		-34	-85	51
MCA		-85	-104*	—
Q	3D	+9	-43	52
UCU (?)		-43	-49	5
UCA (?)		-49	-60	12
MCU		-60	-101	41
MCA		-101	-121*	—
Q	4D	+4	-88	92
UCU		Not present		
UCA		Not present		
MCU		-88	-112	24
MCA		-112	-128*	—

Table 4.4-2

Hydrostratigraphic Unit Elevations from Gamma Ray Logs
Enterprise Avenue Site
(Continued)

Unit	Monitor Well ID	Top (ft, MSL)	Bottom (ft, MSL)	Thickness (ft)
Q	5D	9	-49	58
UCU		-49	-53	4
UCA		-53	-68	15
MCU		-68	-78	10
MCA		-78	-104	26
LCU		-104	-139*	—
Q	6D	9	-41	50
UCU		-41	-46	5
UCA		-46	-67	21
MCU		-67	-91	24
MCA		-91	-104*	—

* - Unit not completely penetrated.
— - Not calculable.
Q - Quaternary deposits.
UCU - Upper confining unit.
UCA - Upper confined aquifer.
MCU - Middle confining unit.
MCA - Middle confined aquifer.
LCU - Lower confining unit.

4.4.2.2 Post-Cretaceous Deposits

The post-Cretaceous deposits are composed mostly of Recent Delaware River sediments and Pleistocene Age sediments. In MW-3D and MW-4D, some Pleistocene Age sands and gravels may occur in the lower part of the Quaternary section. At the location of these latter holes, all of the Cretaceous sediments above the middle confining layer (see Table 4.4-1) have been eroded by the ancestral Delaware River and replaced with Quaternary alluvium. At MW-4D, the post-Cretaceous sediments are about 85 feet thick with coarse sands and large gravel occurring in the lower part. The gamma log indicates a gradual fining upward to silts and silty sands above approximately 40 feet (log datum). The gamma log from well MW-5D to the east of MW-4D indicates a Quaternary section of about 58 feet in thickness. Both wells appear to have been drilled into a paleovalley of the Delaware River. In the other four deep holes, the Quaternary section is composed of silts and fine sands, indicative of overbank conditions.

Descriptive logs from all but well MW-3D indicate an organic layer at an elevation of about -15 feet MSL. The layer is believed to be a buried marsh deposit and is a key marker horizon on the gamma log. Sands occurring between this layer and the upper confining unit are assumed to be Quaternary, based on sorting and composition, although no age dating is available.

4.4.2.3 Upper Confining Unit

In wells MW-1D, MW-5D, and MW-6D, the Quaternary rests unconformably upon a brown clay which is designated as the upper confining unit, and from its stratigraphic position, appears to be equivalent to the Upper clay member of Greenman and others (1961). The age of the clay is assumed to be Cretaceous. The maximum thickness of the upper confining unit is 10 feet, but the clay has been completely eroded at the locations of wells MW-2D and MW-4D. In well MW3-D, the subdued peak on the gamma log just above 55 feet (log datum) may represent a silty phase of the unit.

4.4.2.4 Upper Confined Aquifer

The upper confined aquifer is designated by its position beneath the upper confining unit and appears to occupy local erosional valleys in an underlying clay (middle confining unit). The unit can be identified in monitoring wells 1D, 5D and 6D where it is consistently about 15 feet thick and is composed of gravelly sand to sandy gravel. In wells MW-2D and MW-4D, the unit has been entirely eroded and replaced with Quaternary fluvial deposits. In MW-3D, the aquifer may be present as the sandy unit between 55 and 73 feet (log datum), but the correlation is uncertain.

4.4.2.5 Middle Confining Unit

The geophysical logs are generally dominated by the high amplitude signal of the relatively thick, middle confining unit. The unit is characterized by red and white or multicolored clays that are regionally typical of Cretaceous overbank deposits. The thickest section of the unit is represented on the log from MW-2D where it occupies the interval from approximately 42 feet to 95 feet (log datum). A comparison of logs from MW-2D and MW-6D indicates that about half of the unit thickness, as measured in MW-2D, has been eroded in MW-6D and replaced with sands of the upper confined aquifer. In MW-5B, the unit is only about 10 feet thick.

4.4.2.6 Middle Confined Aquifer

The course-grained sands and gravels underlying the middle confining unit are designated here as the middle confined aquifer. An erosional unconformity marks the top of the aquifer on logs from five of the six deep wells and is particularly distinctive on the log from well MW-1D. The bottom of the unit was not reached except in well MW-5D, where it is approximately 46 feet thick. As indicated above, the middle confining unit, separating the upper confined aquifer from the middle confined aquifer in MW-5D, is relatively thin. These two aquifers could be considered a single unit in well MW-5D.

4.4.2.7 Lower Confining Unit

The basal red and white clay in well MW-5D is tentatively designated as a third confining unit and the lowest penetrated by the project borings. The gamma log indicates that the unit grades downward into a silt or silty sand. Log signatures for the other two confining units have a relative consistent amplitude with sharp upper and lower contacts. The top of the unit in well MW-5D is at an elevation of approximately -103 MSL, lower than projected elevations for the middle confining unit after accounting for an apparent regional dip.

4.4.3 <u>Electromagnetic Induction Logging</u>

4.4.3.1 Purpose and Theory

A brief general discussion of geophysical logging was provided in Subsection 4.4.1. This section specifically describes electromagnetic induction logging and its application to the EAL site.

The electromagnetic induction log (also known as a conductivity log) measures the electrical conductivity of the material surrounding the borehole by inducing an alternating current into the borehole at a frequency of about 20 kilohertz (kHz). The current is introduced by a transmitting coil in the downhole tool and forms a circular pattern around the borehole. The resulting magnetic field induces a secondary current around the borehole that in turn produces a secondary magnetic field. The secondary magnetic field is detected by a receiver coil spaced several tens of centimeters away from the transmitting coil. The voltage developed in the receiver coil by the secondary field is in phase with the transmitter current and directly proportional to the formation conductivity. The primary transmitter signal produces an out-of-phase voltage in the receiver coil, which is rejected by the tool circuitry. Most logging tools also have additional coils that help focus the primary current, thereby providing increased vertical and radial resolution.

Conductivity logs generally provide the best results in high conductivity (low resistivity) environments. The measured conductivity value is a function of both the formation matrix and the conductivity of the interstitial fluid. In a fresh water geologic section, clays or fine-grained sediments usually have higher electrical conductivities than sands. This generality often does not hold, and conductivity logs should be carefully compared to a gamma ray log to establish lithology. Sands containing brackish or salt water, however, will exhibit high conductivities, the exact value being dependent on the composition of the water. In environmental work, the conductivity log is usually run to locate zones of high salinity water. The purpose of the conductivity logging at the EAL site was to determine conductivity trends due to water quality differences and to detect discrete zones containing high conductivity water.

Because the conductivity log is based on an electromagnetic induction principle, it can be run in an open-air or water-filled borehole, or inside nonconductive casings such as PVC. The log is usually calibrated in millimhos per meter (mM/m) or the equivalent international unit - millisiemens per meter (mS/m).

4.4.3.2 Conductivity Log Interpretation

Conductivity values are a composite of the effects of the formation lithology, matrix geometry, and interstitial water quality. In cased holes, well construction may also significantly affect the readings made with portable equipment because of the relatively shallow depth of investigation of the tool. In petroleum logging work, the TDS (or NaCl) content of the formation waters is routinely determined from conductivity logs. In environmental work, however, the results of this calculation should be interpreted cautiously because of the generally low TDS content of the formation water and the shallow depth of investigation. In this investigation, both a qualitative and quantitative approach were attempted to determine if formation water quality could be predicted from the logs.

4.4.3.3 General Log Character

Individual logs are included in Appendix H. Formation conductivity values ranged from zero to slightly over 1,000 mM/m and fluctuated widely over short-depth intervals. A recorded value of zero, or near zero, implies a very low conductivity (high resistivity) that is outside the range in which the logging tool provides accurate measurements. The absolute values in some cases appear to be higher than might be expected from local experience for the TDS content of the formation waters. In formations containing water of higher salinity, variations in the conductivity may often be interpreted as variations in water quality.

Comparison of the gamma ray and conductivity logs showed that the response of the conductivity logs to lithology was subdued and, in some cases, inconsistent from well to well. However, the comparison indicated that higher zones of conductivity were often located above clays or confining beds, particularly at shallow depths. In well WM-1M, for instance, conductivities average about 250 mM/m above the organic silty or silty clay of Recent Age, which occurs at an elevation of about -15 feet MSL across the site. Conductivity at the top of clay drops to zero (or near zero) through the clay, increasing to about 150 mM/m below the clay. Conductivity again increases downward through the remaining Quaternary section as the top of the upper confining unit is approached. The same pattern occurs in WM-5M above the upper confining unit and in WM-6M above the Recent Age marker clay. In these cases, the logs may be indicating zones of higher conductivity water on top of the confining units. Two anomalously high conductivity zones occur on the log from WM-5D. One zone is located from 75 to 80 feet (log datum) and the second is located from 35 to 37 feet. The gamma ray log indicates that both zones are silty lenses within the clay of the middle confining unit, which has a total thickness of about 41 feet in MW-5D. The reason for these anomalies are unknown, but is most likely due to trapped water containing higher TDS.

4.4.3.4 Water Quality Prediction

A standard method to predict the total dissolved solids content (or NaCl) of the formation water is to use the relationship:

$$R_o = FR_w \qquad (1)$$

where: Ro_o = formation resistivity from the geophysical log
F = formation factor
R_w = resistivity of the formation water

The formation factor (F) accounts for the geometry and physical characteristics of the formation matrix. Once F is known, it can then be used to predict gross water quality directly from a resistivity or conductivity log. The applicability of equation (1) was considered in this investigation even though it was developed initially for use in brackish water. F might be calculated by using field measurements of the water conductivity (G_w) where:

$$G_w = \frac{1}{R_w}$$

and using the conductivity log reading at the sampling depth to find R_o where:

$$R_o = \frac{1}{G_o}$$

The highly variable conductivity values made it difficult to select a value for the screened zone where the water quality sample was obtained. The resulting range of F values that could be calculated was too wide to be useful. WESTON suspects that well construction, particularly the gravel pack, is also influencing the log conductivity. The relatively low TDS content of the formation waters also strains the validity of the method.

4.4.3.5 Summary

The conductivity logs appeared to be influenced by a number of variables, which limit the usefulness of the logs as a consistent indicator of water quality. The logs did indicate a weak trend of generally higher conductivity in the medium depth wells than in the deep wells. This trend agrees with the results of the water quality sampling. The wide variability in readings within short-depth intervals makes it difficult to apply quantitative techniques for calculating water quality or monitoring water quality with time. Difficulties are due to 1) the short radial investigation of the tool (about 16 inches); 2) the generally low TDS content of formation waters; and 3) the unknown effect of well construction on the conductivity readings.

4.5 HYDROLOGIC IMPLICATIONS OF SITE LITHOLOGY

A major concern at the EAL site is the potential for contamination of artesian aquifers below the water table aquifer. Quaternary and Pleistocene Age sands generally comprise the water table aquifer, although it is possible that some Cretaceous Age sands exist on top of the middle confining unit. Thus, it was critical in the investigation to define the extent and thickness of confining units between the water table aquifer and the deeper aquifers.

The protection against downward migration of shallow groundwater provided by the various confining units varies with location. On the north and west sides of the landfill, clays dominate the geologic section to a depth of about 90 feet below MSL (about 100 feet below land surface). Clays account for at least 60 feet of the first 100 feet of section in MW-2D (northeast side of landfill). The Cretaceous Age clay of the middle confining unit is about 50 feet thick. The upper confining unit is absent, but the organic silty clay of the overlying Quaternary deposits provides another 10 feet of separation between the upper part of the water table aquifer and the uppermost artesian aquifer (the middle confined aquifer).

The thickness of the middle confining unit in the northwest side of the landfill, at well MW-1D, is about 30 feet (excluding the silts and fine sands that occupy approximately the lower 10 feet of the unit). The presence of the upper confining unit, however, provides an effective total clay thickness of about 40 feet between the water table aquifer and the middle confined aquifer, and a 10-foot thick separation to the upper confined aquifer. The section on the west side of the landfill to about -90 feet (MSL) in well MW-6D is somewhat sandier and the total thickness of the Quaternary silt, the upper confining unit, and the lower confining unit is about 35 feet. The middle confining unit accounts for about 25 feet of this total thickness.

On the southern and eastern sides of the landfill, closer to the Delaware River, all of the upper confining unit is missing in wells 3D, 4D, and 5D. In MW-4D, for example, the water table aquifer is nearly 90 feet thick and is comprised largely of coarse sands and gravels. This thick surficial sand and gravel layer possibly represents the area where the back channel of the Delaware existed until the early 1900s and may act as a pathway for the movement of brackish water from the Delaware River into deep sand. The upper confining unit is missing. Instead, the water table aquifer is underlain by about 25 feet of a tight clay, which is probably the middle confining unit. Where present, the clay is an effective barrier to downward vertical flow. The areal extent of the clay beneath the Delaware River is unknown.

The log from monitoring well 3D is very similar to that of 4D, although the middle confining unit is somewhat thicker. Location 3D likewise appears to be in the abandoned river channel.

In summary, the greatest total thickness of confining units occurs on the northern portion of the landfill where the upper portion of the Cretaceous section is present. Total clay (or silt) thickness exceeds 50 feet. Total clay thickness is least on the eastern side of the landfill where a former channel of the Delaware River has eroded part of the Cretaceous Age sediments. Clay in the eastern area of the site exceeded 24 feet in thickness with one exception, well MW-5D, where the clay thickness is 14 feet. Nevertheless, the minimum thickness of fine-grained material separating the water table aquifer from the Cretaceous sands below the middle confining unit is approximately 14 feet.

4.6 SUMMARY

- The EAL site lies within the Atlantic Coastal Plain Physiographic Province.

- Philadelphia is underlain by crystalline rocks and by the younger unconsolidated sediments of the Coastal Plain. Productive sources of groundwater are found in Cretaceous Age sediments that have accumulated in the ancestral Schuylkill and Delaware River channels.

- The EAL site lies in the axis of the south-trending Point Breeze trough. A bedrock high is present east of the EAL site.

- The four major overburden stratigraphic units encountered at the EAL are:

  1. Fill material.
  2. Quarternary Age alluvium (Qal).
  3. Pleistocene Age sands and gravels (Qp).
  4. Cretaceous Age interbedded sands and gravels with silts and clays of the Potomac-Raritan-Magothy Formation (Kprm).

- Gamma and electromagnetic (EM) geophysical logging techniques were employed on the newly installed intermediate and deep wells.

- Gamma logs were used to identify and correlate stratigraphic units at each of the six well sites.

- EM logging results were inconclusive, probably due to low concentrations of Total Dissolved Solids in the formation waters.

- A thick layer of clay, ranging from 25 to 60 feet in thickness is present in 5 of the 6 deep wells. The sixth well has a series of clay layers ranging from 4 to 14 feet thick. These clay layers separate the water table aquifers from the Cretaceous sand units.

SECTION 5
HYDROGEOLOGY

5.1 INTRODUCTION

This section discusses the hydrogeological data that were collected during the Phase I field effort. The site hydrogeological section specifically discusses the installation of monitor wells; groundwater levels; the direction of groundwater flow; horizontal and vertical gradients; and the quality of the groundwater in the shallow, intermediate, and deep water-bearing zones at the EAL. The deep water-bearing zone correlates to the MCA of the Kprm described in Subsection 4.4.2.6. In order to maintain consistency with well nomenclature, the MCA is referred to as the deep water-bearing unit in this section.

5.2 SITE HYDROGEOLOGY

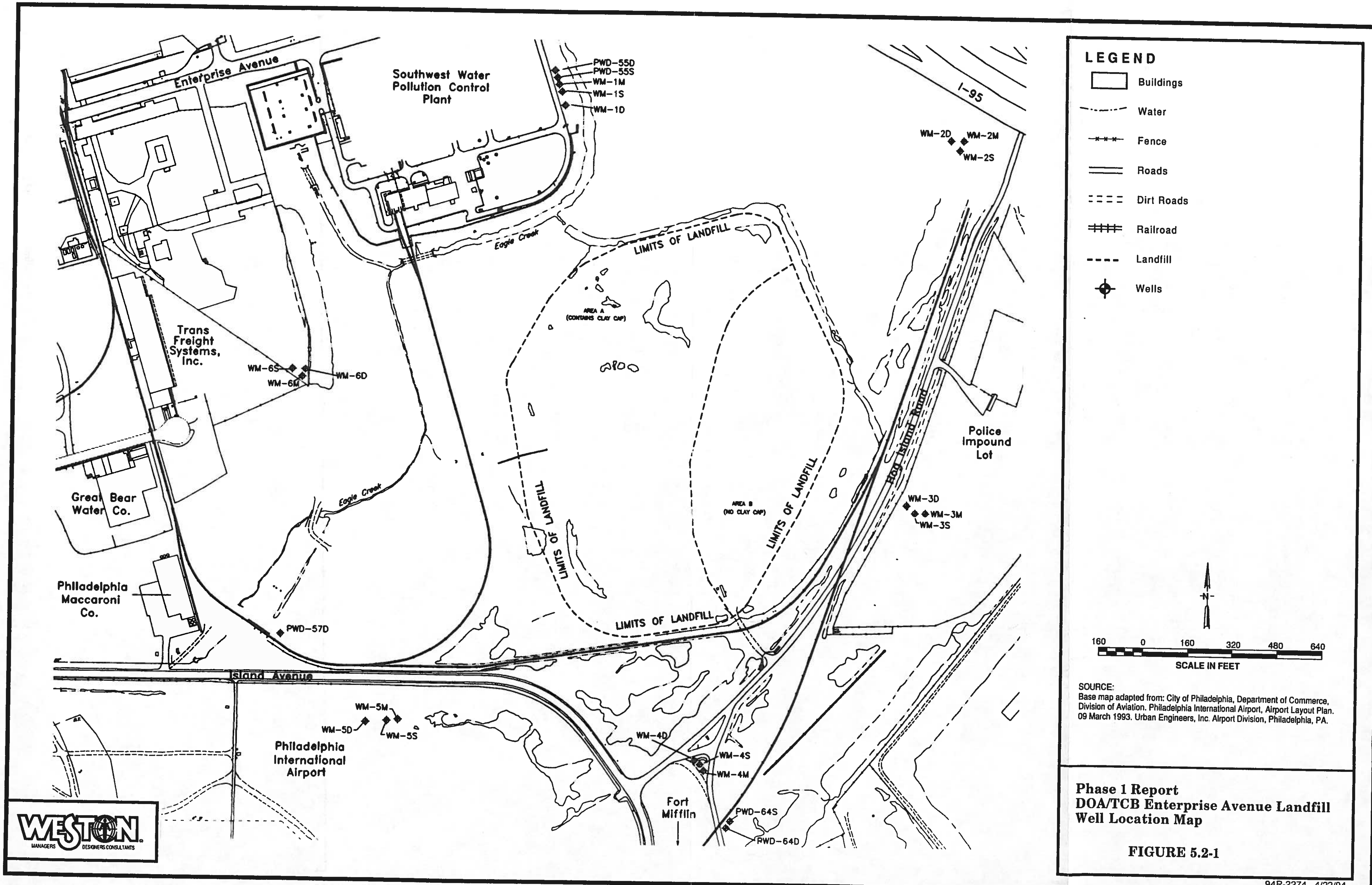
During the Phase I field effort at the EAL, 18 groundwater monitoring wells were installed in January and February 1994. Monitor wells were installed in a radial pattern as well as triplets (WM-1 through WM-6) at six locations agreed upon by WESTON and EPA. Each well triplet consisted of one well screened in the shallow water-bearing zone, one well screened in the intermediate water-bearing zone, and one well screened in the deep confined water-bearing zone (MCA). Well locations are presented in Figure 5.2-1. Well triplet WM-1 is located northwest of EAL on the southeast side of the Philadelphia Water Pollution Control Plant. Eagle Creek is located approximately 75 feet east of WM-1. WM-2 is located northeast of EAL near I-95. WM-3 is located east of EAL in the Philadelphia Police Department's Automobile Impound Lot on Hog Island Road. WM-4 is located south of EAL on Hog Island Road near the entrance to Fort Mifflin. WM-5 is located southwest of EAL within the boundaries of the Philadelphia International Airport. WM-6 is located west of EAL near the Trans Freight Systems Inc. property. A summary of the monitor well construction details is presented in Table 5.2-1. Well construction diagrams are provided in Appendix G. The lithology of the water-bearing units in which the wells are screened is presented in Figures 4.3-1 through 4.3-6 in Section 4.

Table 5.2–1

Enterprise Avenue Landfill
Phase I — Groundwater Monitor Well Construction Summary

Well ID	Date of Installation	Well Diameter (inch)	Inner Casing Elevation (ft MSL)	Outer Casing Depth (ft BGS)	Inner Casing Stickup (feet)	Top Screen Depth (ft BGS)	Bottom Screen Depth (ft BGS)	Screen Length (ft BGS)	Well Total Depth (ft BGS)	Borehole Total Depth (ft BGS)	Unit Screened
WM–1S	1/22/94	4	7.11	NA	2.70	10.00	15.00	5.00	15.00	15.00	Fill/Qp
WM–1M	1/22/94	4	6.88	NA	2.50	28.00	37.00	9.00	39.70	44.00	Qp
WM–1D	2/16/94	4	9.35	78.00	2.50	115.63	124.63	9.00	128.00	134.00	Kprm
WM–2S	1/27/94	4	8.89	NA	2.00	15.50	24.50	9.00	27.00	27.00	Qal
WM–2M	1/26/94	4	9.30	NA	2.00	39.00	47.00	8.00	47.00	47.00	Qp
WM–2D	2/2/94	4	9.64	55.00	2.60	101.73	110.73	9.00	114.00	117.50	Kprm
WM–3S	1/27/94	4	8.53	NA	2.00	18.50	27.50	9.00	30.00	30.00	Qal
WM–3M	1/25/94	4	9.34	NA	2.00	35.50	44.50	9.00	47.00	48.50	Qp
WM–3D	2/18/94	4	8.83	73.00	2.65	118.00	127.00	9.00	130.00	137.00	Kprm
WM–4S	1/22/94	4	4.45	NA	2.50	8.50	17.50	9.00	20.00	20.00	Qal
WM–4M	1/22/94	4	4.27	NA	2.00	42.50	51.50	9.00	54.00	66.00	Qp
WM–4D	2/18/94	4	4.08	98.00	2.00	121.40	130.40	9.00	133.00	135.00	Kprm
WM–5S	2/2/94	4	7.14	NA	1.80	8.50	17.50	9.00	20.00	20.00	Qal
WM–5M	2/1/94	4	7.60	NA	2.00	38.00	47.00	9.00	49.50	56.00	Qp
WM–5D	2/28/94	4	8.58	116.50	2.00	128.60	137.60	9.00	140.20	143.00	Kprm
WM–6S	2/8/94	4	9.46	NA	2.10	13.50	22.50	9.00	25.00	25.00	Fill/Qal
WM–6M	2/7/94	4	10.55	NA	3.20	37.50	46.50	9.00	49.00	49.00	Qp
WM–6D	2/28/94	4	9.34	79.00	1.90	102.50	111.50	9.00	114.00	118.00	Kprm

ft BGS – Feet below ground surface.
ft MSL – Feet above mean sea level.
NA – Not applicable.



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Well Location Map

FIGURE 5.2-1

5.2.1 <u>Groundwater Monitor Well Installation</u>

5.2.1.1 Shallow Wells

The shallow wells were installed at each of the six locations between 22 January 1994 and 2 February 1994. All the shallow wells were screened in the fine sandy silty clay (Qal) layer with the exception of WM-1S and WM-6S. WM-1S was screened in a sandy fill material. WM-6S was screened approximately 1.5 feet in the fill and 7.5 feet in the Qal layer. The screen depths of the shallow wells ranged from 8.5 to 24.5 feet bgs. WM-3S, WM-4S, WM-5S, and WM-6S were constructed with a 9-foot screen. WM-1S and WM-2S were screened with a 5 and 8-foot screen, respectively. Wells WM-1S and existing well PWD-55S were screened at similar depths within the same hydrologic unit. Existing well PWD-64S is located approximately 250 feet south of WM-4, with an unknown screen interval. Its total depth, as measured during the existing well survey, is 9.65 feet bgs, whereas WM-4S was screened from 8.5 to 17.5 feet bgs.

5.2.1.2 Intermediate Wells

The intermediate wells were installed at each of the six locations between 22 January 1994 and 7 February 1994. All intermediate wells were screened in the Qp layer with a 9-foot screen. The screen depth of the intermediate wells ranged from approximately 37 to 51.5 feet bgs. Well WM-1M and existing well PWD-55D were screened in the same hydrologic unit; however, WM-1M is slightly deeper than PWD-55D. Existing well PWD-64D is located approximately 250 feet south WM-4M and has an unknown screen interval. Its total depth, as measured during the existing well survey, is 29.21 feet bgs, whereas WM-4M was screened from 42.5 to 51.5 feet bgs.

5.2.1.3 Deep Wells

The deep wells were installed at each of the six locations between 2 February 1994 and 28 February 1994. The deep wells were screened in the first sand unit encountered below the Kprm silty clay at depths ranging from approximately 101 to 137 feet bgs (MCA). These sands and gravels were variable in color and tended to coarsen with depth. The confining layer consisted of a silty clay layer which ranged in thickness from 45 to 57 feet in wells WM-1D, WM-2D, and WM-3D. In wells WM-4D and WM-6D, the confining layer was approximately 25 feet thick. In WM-5D, the confining layer consisted of interbedded silty clays and silty sands. Four prominent beds of silty clay were identified, with three beds having a thickness of approximately 4 feet, and one bed having a thickness of approximately 12 feet. Each of these wells is double cased with the outer casing grouted into the confining layer.

5.2.2 Water Level Measurements

Groundwater elevations were measured manually on 11, 15, 18, 22, and 28 March 1994 and are presented in Table 5.2-2. Groundwater levels were also monitored at 5-minute intervals, using automatic data loggers, from 15 to 28 March 1994 in all Phase I shallow, intermediate, and deep wells, and in existing wells PWD-55S and PWD-55D. These groundwater level data were used to plot individual hydrographs for all wells. Barometric pressure data also were collected from 15 to 28 March 1994 at well location WM-1. Meteorological data, including precipitation and temperature data, were obtained from the National Weather Service at the Philadelphia International Airport. Tidal data for the Delaware River at Philadelphia were obtained from NOAA through the U.S. Army Corps of Engineers.

5.2.2.1 Shallow Wells

The groundwater hydrographs for the shallow wells are presented in Figure 5.2-2. Similar patterns were observed in six of the seven shallow wells. Water level elevations remained relatively constant in all shallow wells except WM-2S. Water level elevations in WM-2S steadily increased from approximately -0.75 to 0.75 feet MSL. Water level elevations ranged from approximately 0.55 feet MSL in MW-4S to approximately -4.7 feet MSL in WM-1S. The highest water levels were observed in WM-6S ranging from approximately 5.4 to approximately 6.1 feet MSL.

Table 5.2-2

Enterprise Avenue Landfill Groundwater Elevations

Well ID	Inner Casing Elevation (ft MSL)	DTW (ft TIC) 3/11/94	GW Elevation (ft MSL) 3/11/94	DTW (ft TIC) 3/15/94	GW Elevation (ft MSL) 3/15/94	DTW (ft TIC) 3/18/94	GW Elevation (ft MSL) 3/18/94	DTW (ft TIC) 3/22/94	GW Elevation (ft MSL) 3/22/94	DTW (ft TIC) 3/28/94	GW Elevation (ft MSL) 3/28/94
WM-1S	7.11	10.55	-3.44	11.19	-4.08	11.25	-4.14	11.60	-4.49	11.60	-4.49
WM-1M	6.88	11.55	-4.67	11.51	-4.63	11.55	-4.67	11.78	-4.90	11.67	-4.79
WM-1D	9.35	14.07	-4.72	13.87	-4.52	14.09	-4.74	14.13	-4.78	14.23	-4.88
WM-2S	8.89	11.34	-2.45	9.68	-0.79	9.04	-0.15	8.57	0.32	8.18	0.71
WM-2M	9.30	13.31	-4.01	13.19	-3.89	13.31	-4.01	13.41	-4.11	13.37	-4.07
WM-2D	9.64	14.25	-4.61	14.09	-4.45	14.42	-4.78	14.18	-4.54	14.15	-4.51
WM-3S	8.53	11.26	-2.73	10.75	-2.22	10.97	-2.44	11.00	-2.47	10.96	-2.43
WM-3M	9.34	12.96	-3.62	12.49	-3.15	12.81	-3.47	12.81	-3.47	12.83	-3.49
WM-3D	8.83	13.51	-4.68	12.79	-3.96	13.29	-4.46	12.70	-3.87	13.42	-4.59
WM-4S	4.45	3.86	0.59	3.91	0.54	4.41	0.04	3.98	0.47	3.90	0.55
WM-4M	4.27	6.00	-1.73	7.46	-3.19	7.77	-3.50	7.74	-3.47	7.81	-3.54
WM-4D	4.08	9.20	-5.12	8.11	-4.03	8.37	-4.29	7.54	-3.46	8.54	-4.46
WM-5S	7.14	9.22	-2.08	8.68	-1.54	8.58	-1.44	8.79	-1.65	8.60	-1.46
WM-5M	7.60	11.42	-3.82	11.00	-3.40	11.08	-3.48	11.09	-3.49	11.02	-3.42
WM-5D	8.58	12.61	-4.03	12.48	-3.90	12.28	-3.70	11.78	-3.20	11.65	-3.07
WM-6S	9.46	3.53	5.93	3.46	6.00	3.61	5.85	3.64	5.82	3.59	5.87
WM-6M	10.55	14.71	-4.16	14.36	-3.81	14.51	-3.96	14.60	-4.05	14.56	-4.01
WM-6D	9.34	13.53	-4.19	13.18	-3.84	13.31	-3.97	13.39	-4.05	13.34	-4.00
PWD-55S	4.36	8.01	-3.65	NA	NA	8.61	-4.25	9.11	-4.75	9.16	-4.80
PWD-55D	4.12	7.77	-3.65	NA	NA	8.79	-4.67	9.03	-4.91	8.92	-4.80
PWD-64S	1.76	2.35	-0.59	NA	NA	2.41	-0.65	2.49	-0.73	1.67	0.09
PWD-64D	4.58	8.26	-3.68	NA	NA	8.06	-3.48	7.98	-3.40	8.02	-3.44

FT/TIC – Feet Below Top of Inner Casing.
FT/MSL – Feet Above/Below Mean Sea Level.
NA – Not Available.
DTW – Depth to Water.
GW – Groundwater.
Note: PWD-55S and PWD-64S measurements are taken from top of outer casing.

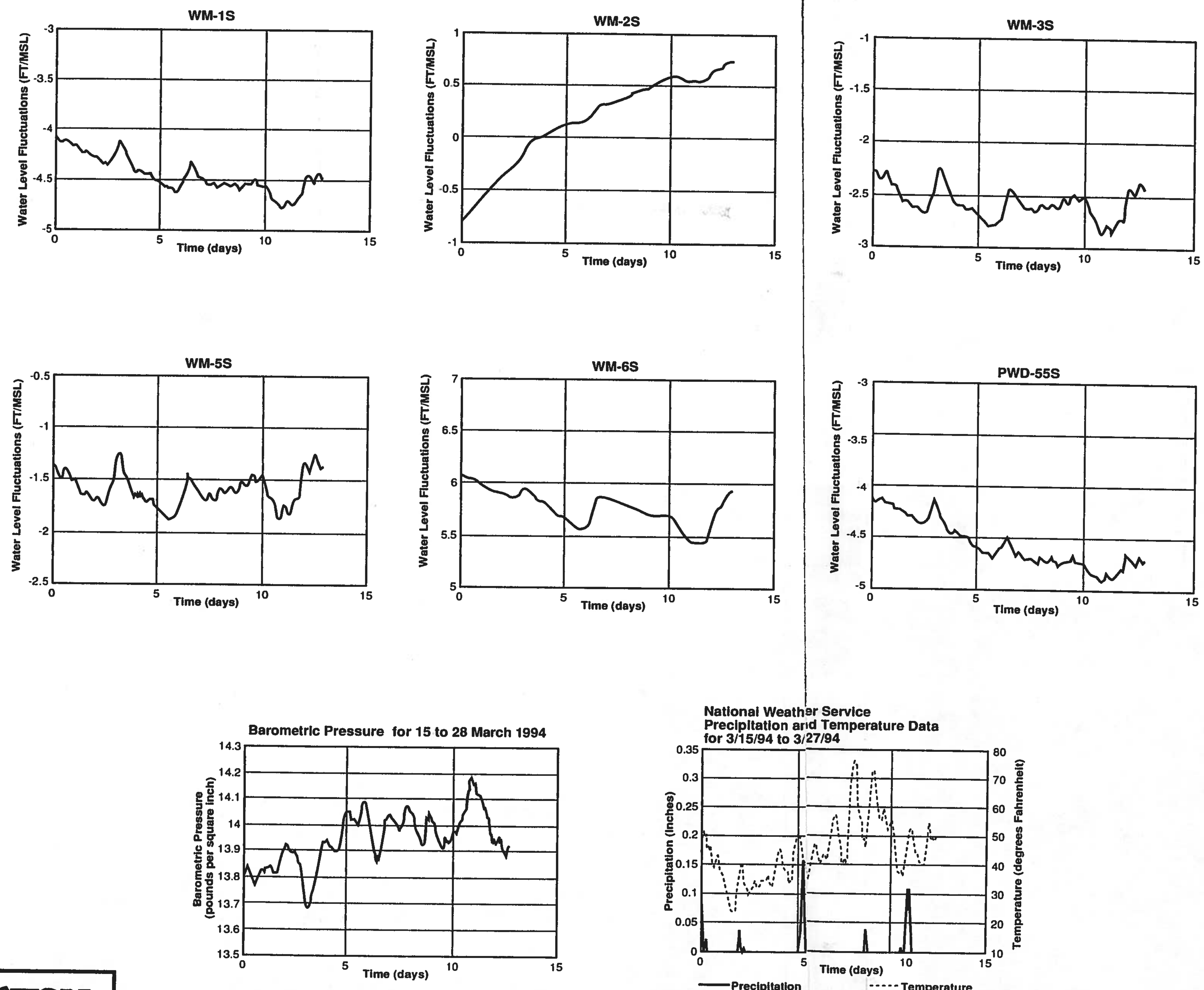
Water level fluctuations in the shallow wells correlate to changes in barometric pressure. This is most apparent in WM-1S, WM-3S, WM-4S, WM-5S, and PWD-55S and to a lesser extent in WM-2S and WM-6S. Water level fluctuations in WM-1S, WM-3S, WM-4S, WM-5S, and PWD-55S also appear to be influenced by tides. Tidal affects were not observed in wells WM-2S and WM-6S. The hydrograph for the Delaware River, illustrating tidal water level changes, is shown in Figure 5.2-3. Precipitation and temperature data was plotted to determine if rainfall and spring thawing influenced water levels in the shallow wells; however, no correlation was observed between precipitation, temperature, and changes in water levels in the shallow wells. Barometric pressure and tidal fluctuations in the Delaware River have the greatest influence on water levels in the shallow wells.

5.2.2.2 Intermediate Wells

The groundwater hydrographs for all of the intermediate wells are presented on Figure 5.2-3. Groundwater elevations ranged from approximately -3.1 feet MSL in WM-3M to approximately -4.6 feet MSL in WM-2M. Fluctuations in water levels were similar in all intermediate wells. Changes in water levels correlate to changes in barometric pressure and tides on the Delaware River. The largest tidal affects were observed in WM-3M, WM-4M, and WM-5M which are located closest to the Delaware River.

5.2.2.3 Deep Wells

The groundwater hydrographs for the deep wells are presented on Figure 5.2-4. Groundwater elevations ranged from approximately -2.8 feet MSL in WM-5D to approximately -5.45 feet MSL in WM-4D. Fluctuations in water levels were similar in all deep wells. Changes in water levels correlate to changes in barometric pressure and tides on the Delaware River. The greatest tidal affects were observed in wells WM-3D, WM-4D, and WM-5D, which are located closest to the Delaware River.

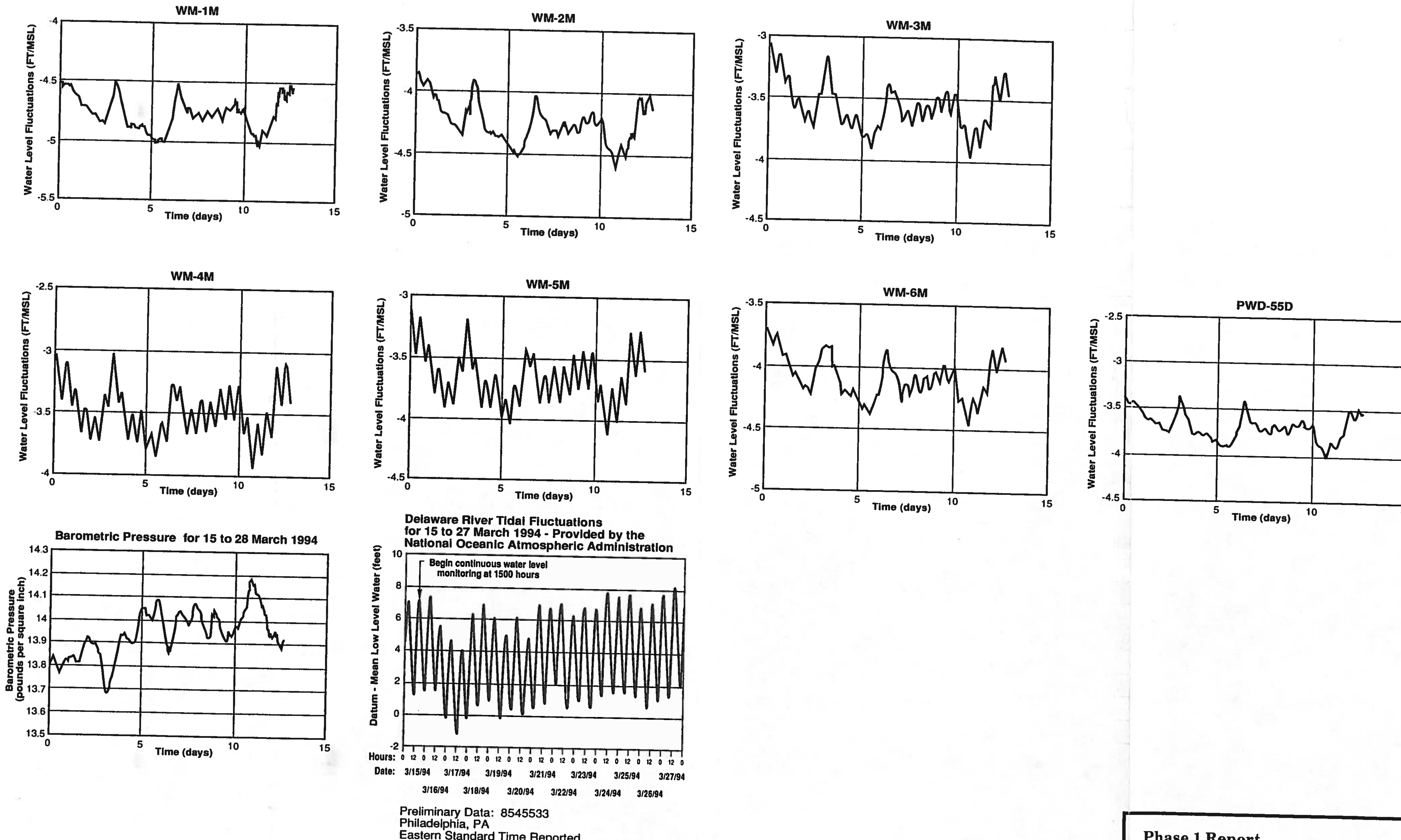


WESTON
MANAGERS DESIGNERS/CONSULTANTS

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Hydrographs – Shallow Wells
15 to 28 March 1994

FIGURE 5.2-2

94P-2236 4/26/94

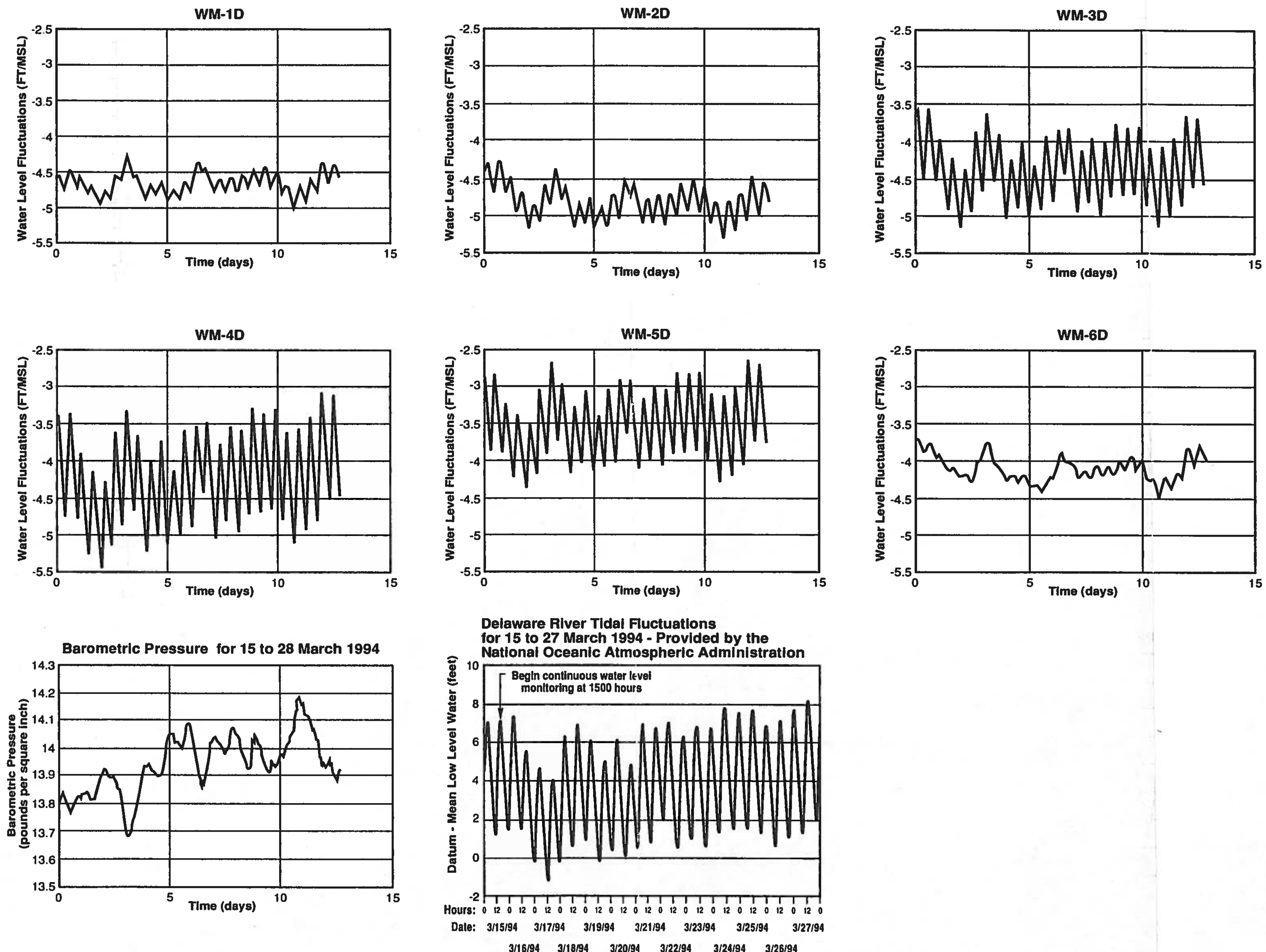


WESTON
MANAGERS DESIGNERS/CONSULTANTS

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Hydrographs – Intermediate Wells
15 to 28 March 1994

FIGURE 5.2-3

94P-2237 4/28/94



Preliminary Data: 8545533
Philadelphia, PA
Eastern Standard Time Reported

WESTON
MANAGERS DESIGNERS/CONSULTANTS

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Hydrographs – Deep Wells
15 to 28 March 1994

FIGURE 5.2-4

94P-2238 4/28/94

5.2.2.4 Summary

The shallow, intermediate, and deep wells at the EAL are influenced by barometric pressure. Shallow wells WM-1S, PWD-55S, WM-3S, WM-4S, and WM-5S; all the intermediate wells; and all the deep wells are also influenced by tides associated with the Delaware River. The tidal forces acting upon the shallow, intermediate, and deep wells are considered rapid phenomena with respect to the porous medium's ability to transmit water. This means that the permeability of the medium actually limits the movement of water into the medium from the surface water body; therefore, the mass of water in the water-bearing medium is considered constant. Since the mass of water present in the water-bearing unit is assumed constant, there is no significant groundwater flow resulting from the tidal fluctuations (Domenico and Schwartz, 1990). The potentiometric surface fluctuations observed in the hydrographs for all three units represent only pressure changes or changes in head and not actual groundwater movement.

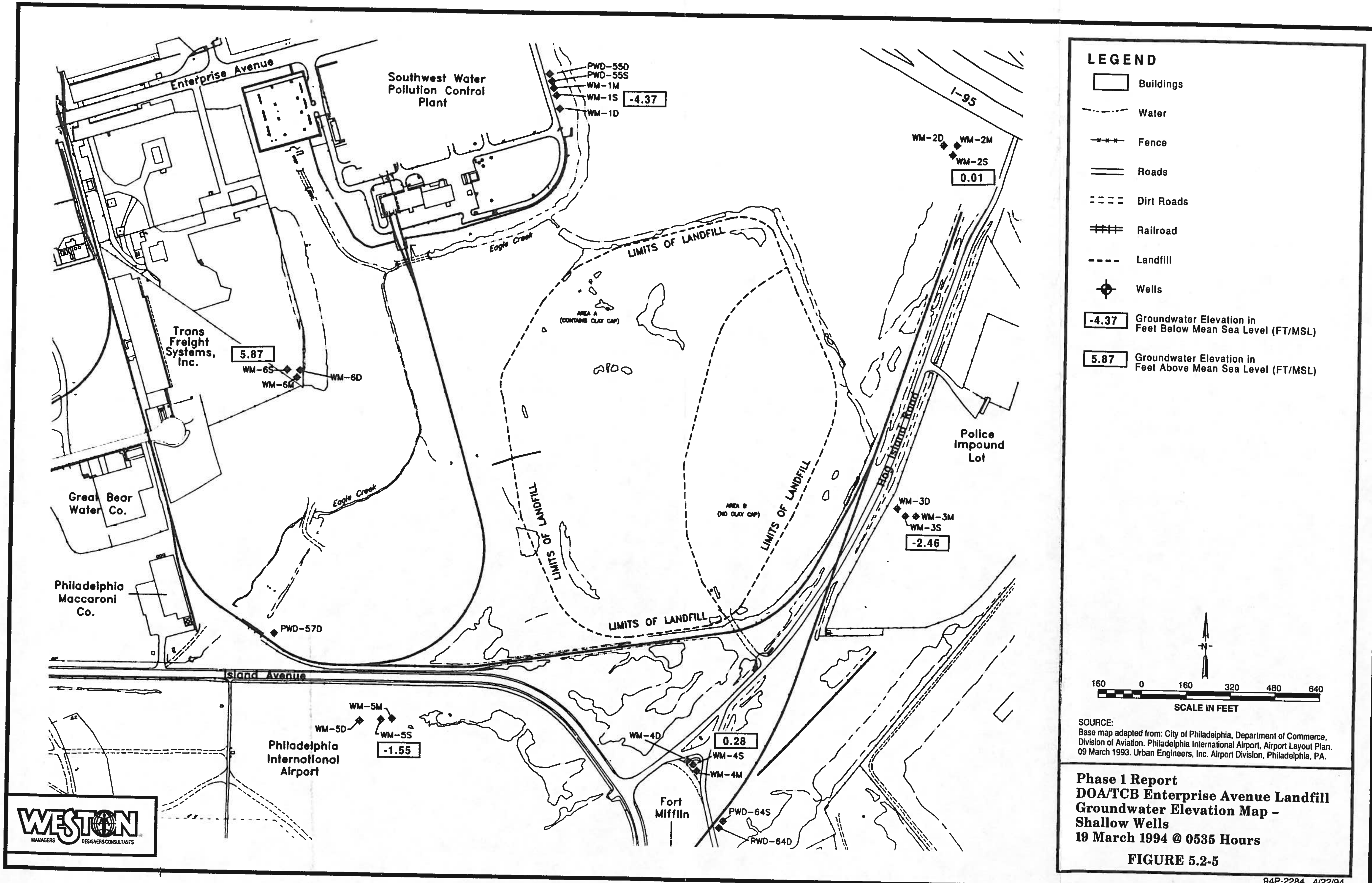
5.2.3 Groundwater Flow

5.2.3.1 Shallow Water-bearing Zone

As shown in Figures 5.2-5 and 5.2-6, the direction of groundwater flow in the shallow water-bearing zone is dependent upon localized conditions at each well with no dominant regional flow pattern. The direction of groundwater flow in the shallow water-bearing zone is complex due to its estuarine origin, the low topographic relief of the area and highly complex local surface drainage. In general, surface water drains towards the north via Eagle Creek into Mingo Creek, which discharges into the Schuylkill River. Surface water runoff from the EAL discharges into Eagle Creek. WM-1S, PWD-55S, and WM-6S are located in the vicinity of Eagle Creek and are most likely affected by flow conditions in Eagle Creek. Therefore, the direction of groundwater flow at WM-1S, PWD-55S, and WM-6S is most likely northeastly. The direction of groundwater flow at WM-2S is uncertain; however, local surface topography suggests the direction of groundwater flow is likely southwestly towards the EAL and the drainage along the perimeter of the EAL. The direction of groundwater flow at WM-4S, PWD-64S, and WM-3S is also uncertain. Surface water in these areas is ponded, and local topography does not suggest a direction for groundwater flow. Groundwater flow direction at WM-5S is likely north towards the EAL; however, insufficient information is available to make this determination. Flow in this area is complicated by a stormdrain system associated with the Philadelphia Airport. Because of these uncertainties, a regional groundwater flow direction could not be assigned for the shallow water-bearing zone.

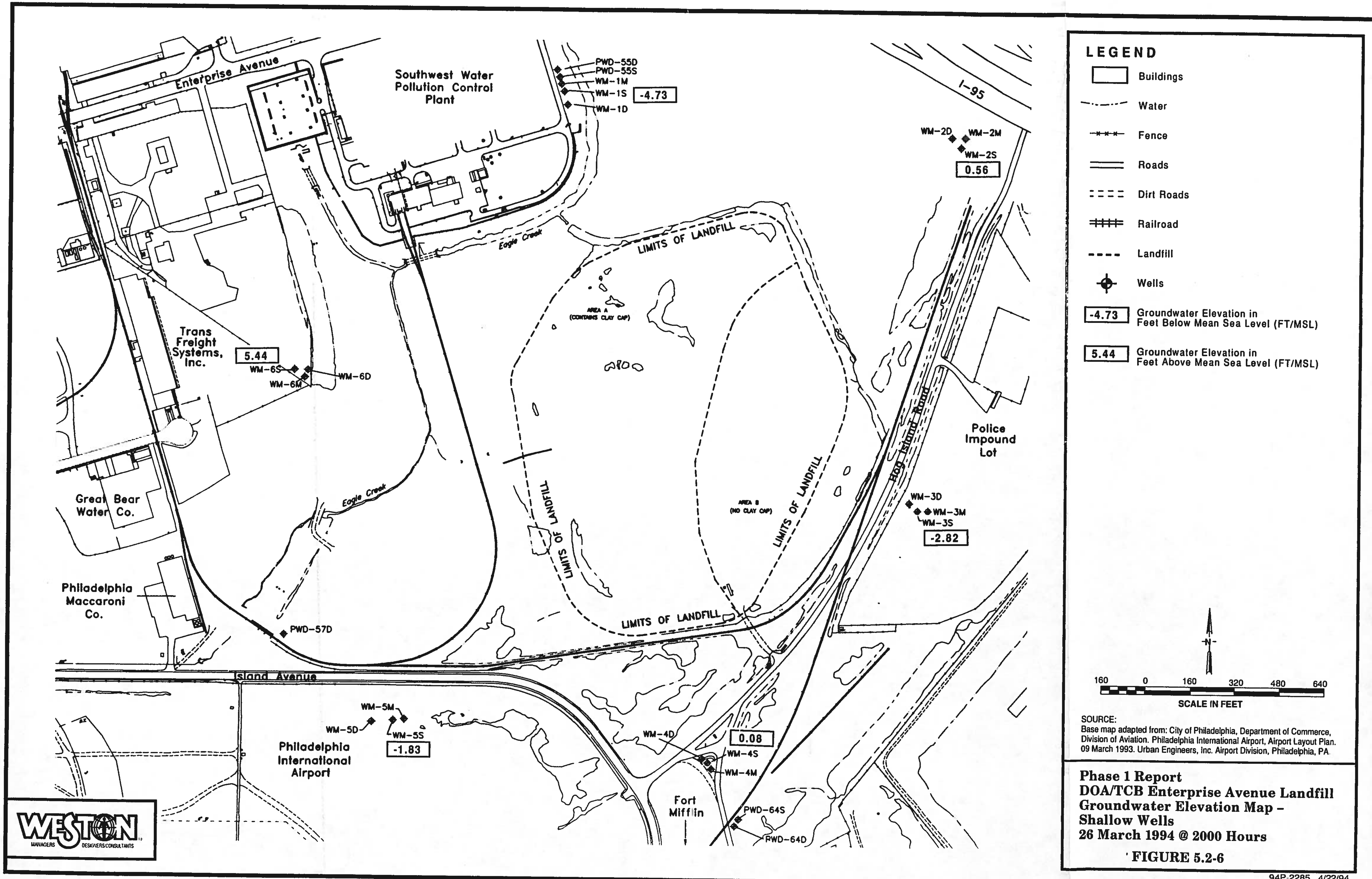
5.2.3.2 Intermediate Water-bearing Zone

As shown in Figures 5.2-7 through 5.2-10, the direction of groundwater flow in the intermediate water-bearing zone is northwesterly. To determine the direction of groundwater flow, individual hydrographs for the intermediate wells were combined into one hydrograph showing all six wells (see Figure 5.2-11). This combined hydrograph was examined for potential adjustments or fluctuations in groundwater flow direction by identifying times when individual well hydrograph lines cross. Three points along the graph showed possible adjustments or fluctuations in groundwater flow direction. A groundwater flow map was then constructed for each of the three times, and the resulting groundwater flow directions were compared. Comparison of these three potentiometric surfaces indicates that there are no significant changes in flow direction associated with the tidal response in the intermediate water-bearing zone. To illustrate the consistency in groundwater flow direction, two of the three times are presented in the form of groundwater flow maps as Figures 5.2-7 and 5.2-8. These times are shown on the hydrograph (Figure 5.2-11) as points A and B. In addition, groundwater flow maps were constructed from data collected six hours after points A and B in order to illustrate the effects of both high and low tidal fluctuations on the observed groundwater flow directions. These groundwater flow maps are presented as Figures 5.2-9 and 5.2-10. Based on the northwesterly direction of groundwater flow shown in Figures 5.2.7 through 5.2.10 (to the north), wells WM-3M and WM-4M are up-gradient;, well WM-1M is down-gradient; wells WM-2M and WM-6M are cross-gradient of the EAL.



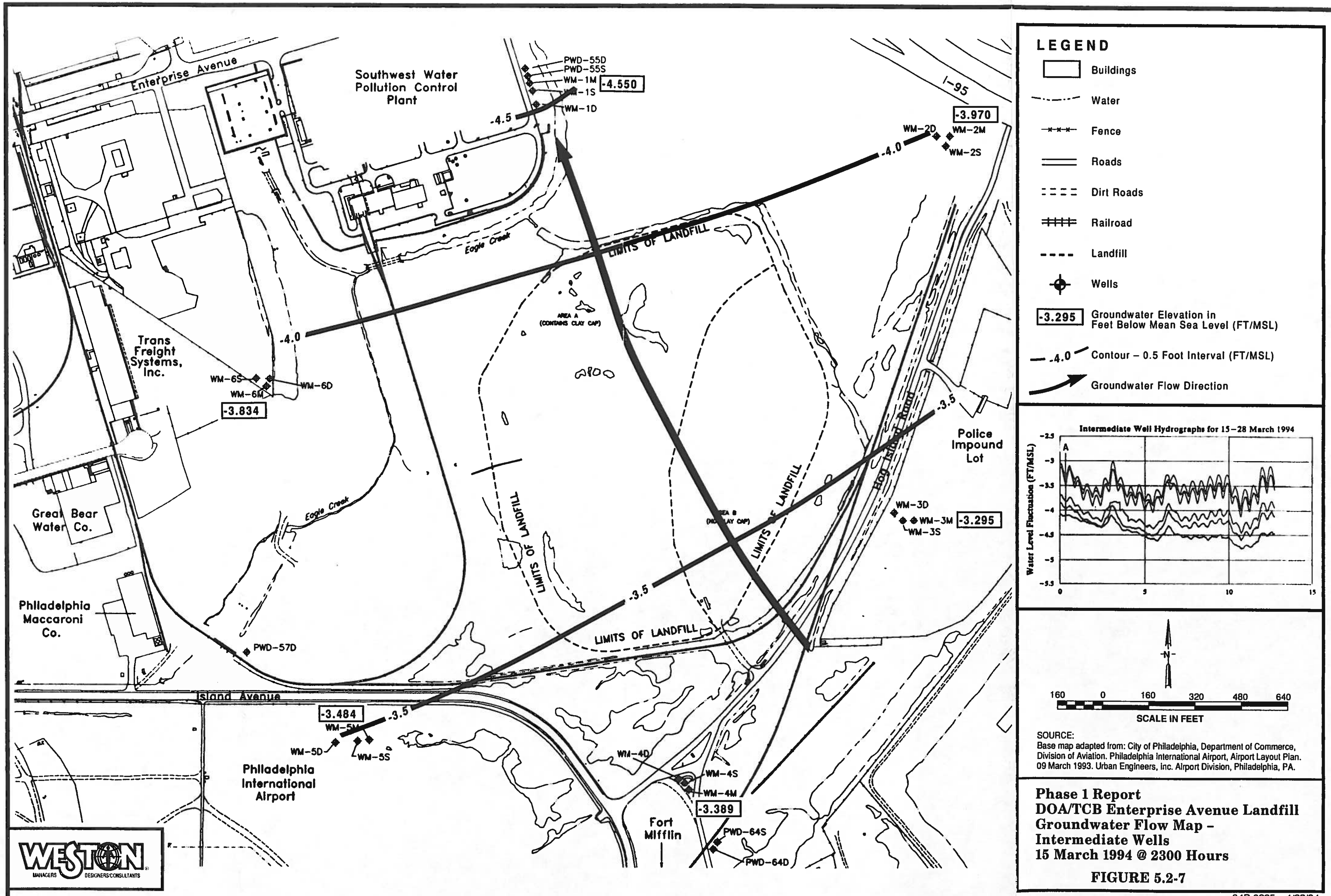
Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Groundwater Elevation Map – Shallow Wells
19 March 1994 @ 0535 Hours

FIGURE 5.2-5



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Groundwater Elevation Map – Shallow Wells
26 March 1994 @ 2000 Hours

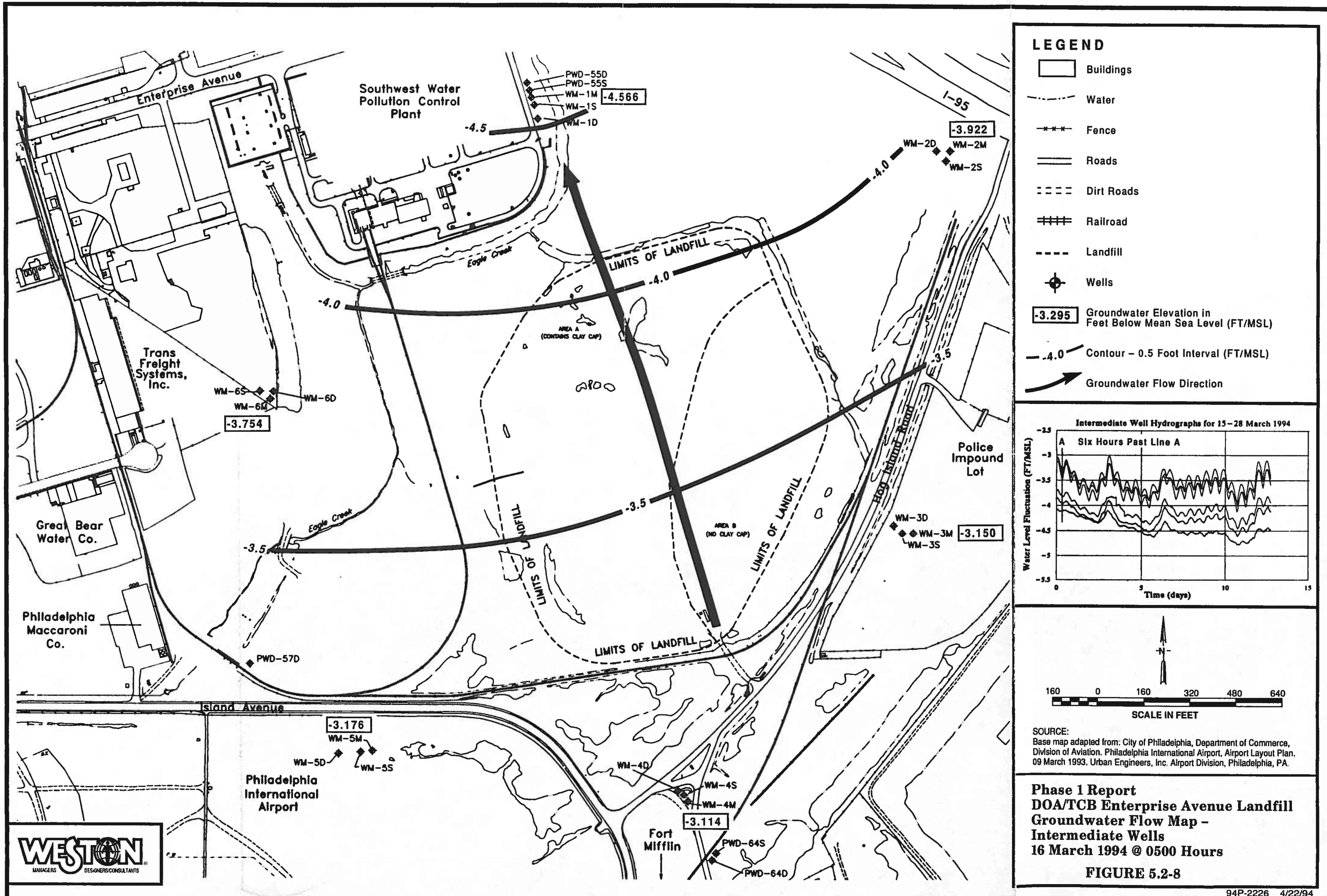
FIGURE 5.2-6



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Groundwater Flow Map – Intermediate Wells
15 March 1994 @ 2300 Hours

FIGURE 5.2-7

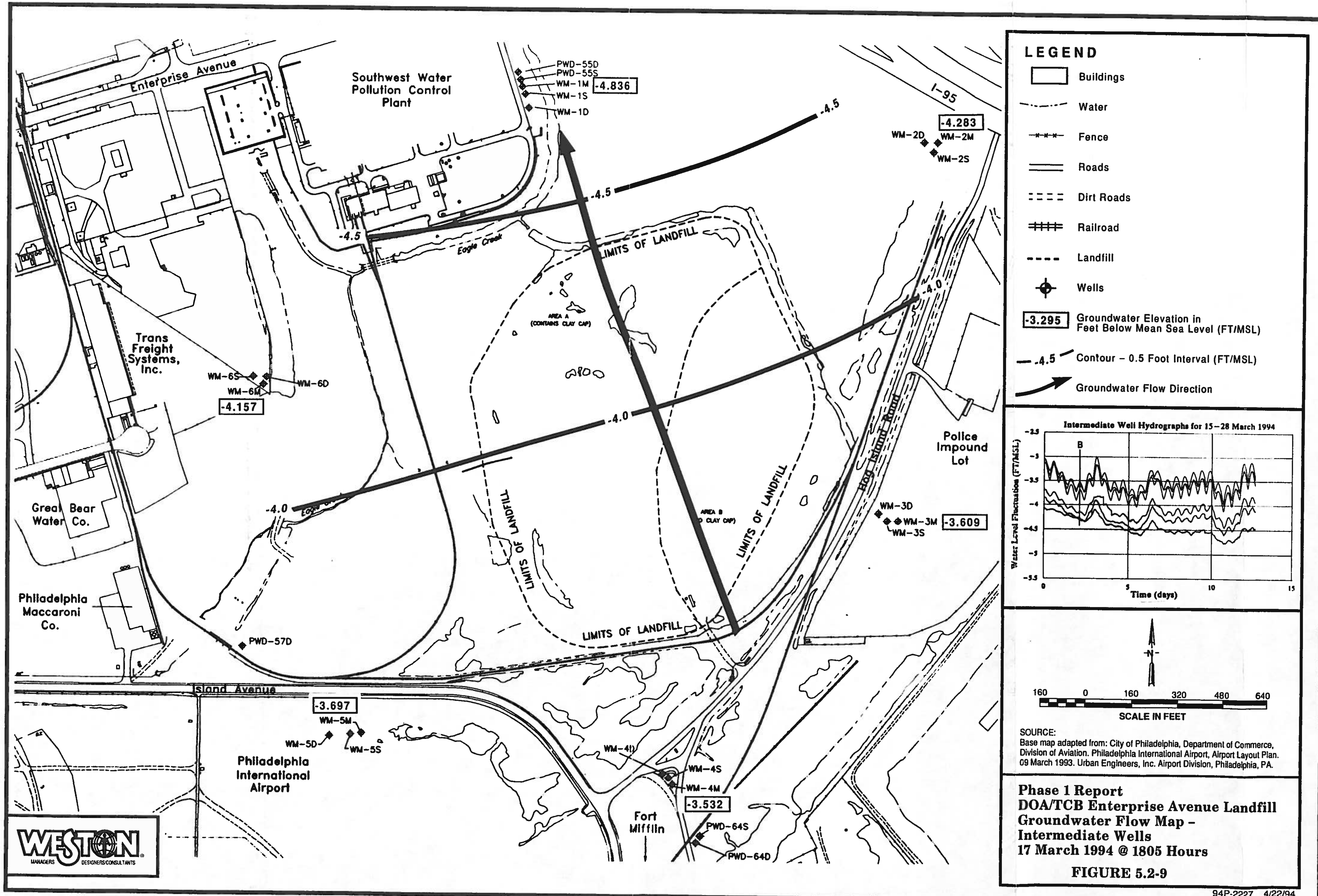
94P-2225 4/22/94



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Groundwater Flow Map – Intermediate Wells
16 March 1994 @ 0500 Hours

FIGURE 5.2-8

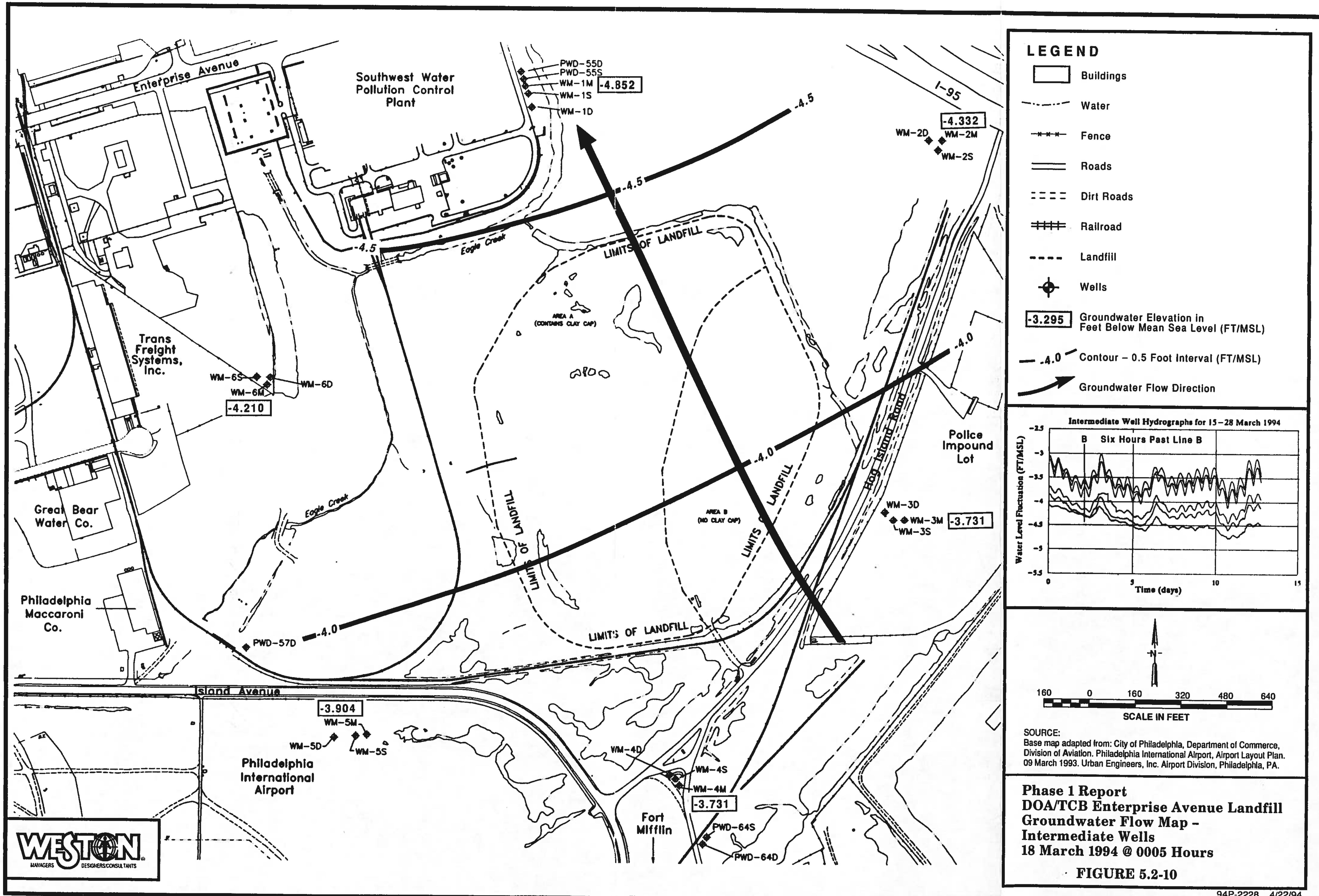
94P-2226 4/22/94



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Groundwater Flow Map -
Intermediate Wells
17 March 1994 @ 1805 Hours

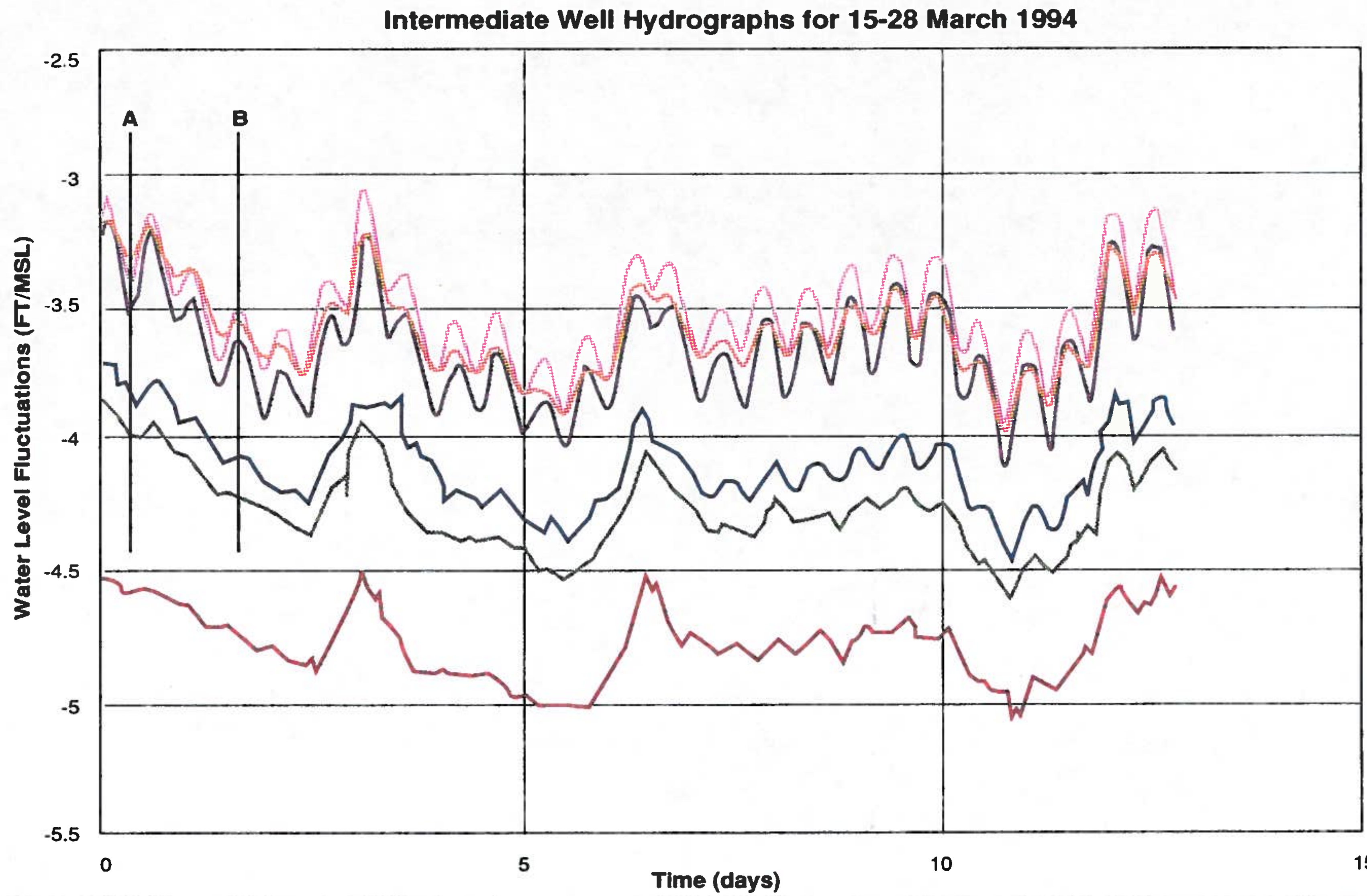
FIGURE 5.2-9

94P-2227 4/22/94



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Groundwater Flow Map - Intermediate Wells
18 March 1994 @ 0005 Hours

FIGURE 5.2-10



LEGEND

WM-1M
WM-2M
WM-3M
WM-4M
WM-5M
WM-6M

WESTON MANAGERS DESIGNERS/CONSULTANTS

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Hydrographs – Six Intermediate Wells
15 to 28-MAR-94

DRAFT FIGURE 5.2-11

94P-2243

5.2.3.3 Deep Water-bearing Zone

As shown in Figures 5.2-12 through 5.2.15, the direction of groundwater flow in the deep water-bearing zone is between the east and northeast. To determine the direction of groundwater flow in the deep water-bearing zone, individual hydrographs for the deep wells were also plotted on one graph (Figure 5.2-16). This combined hydrograph was examined for potential changes in groundwater flow direction by identifying times when individual well hydrograph lines cross. Seven conditions on the hydrograph showed possible adjustments or fluctuations in the direction of groundwater flow. A groundwater flow map was then constructed for each of the seven conditions. In addition, groundwater flow maps were constructed from water levels collected manually on 11 and 28 March 1994. The resulting groundwater flow directions were then compared. Based on this comparison, two points were selected from Figure 5.2-16 to represent the typical range of groundwater flow direction in the deep water-bearing unit. Groundwater flow maps were constructed for times "A" and "B" (see Figure 5.2-16) and 6 hours past these points to reflect changes in groundwater flow during tidal fluctuations. As shown in Figures 5.2-12 through 5.2-15, the direction of groundwater flow in the deep water-bearing zone varies between east and northeast. This analysis also revealed a brief transient swing of groundwater flow direction to the east-southeast during occasional low tides.

Based on the direction of groundwater flow shown in Figures 5.2.12 through 5.2.15, wells WM-1D, WM-2D, and WM-3D are down-gradient; and wells WM-4D, WM-5D, and WM-6D are up-gradient of the EAL.

5.2.4 Horizontal and Vertical Gradients

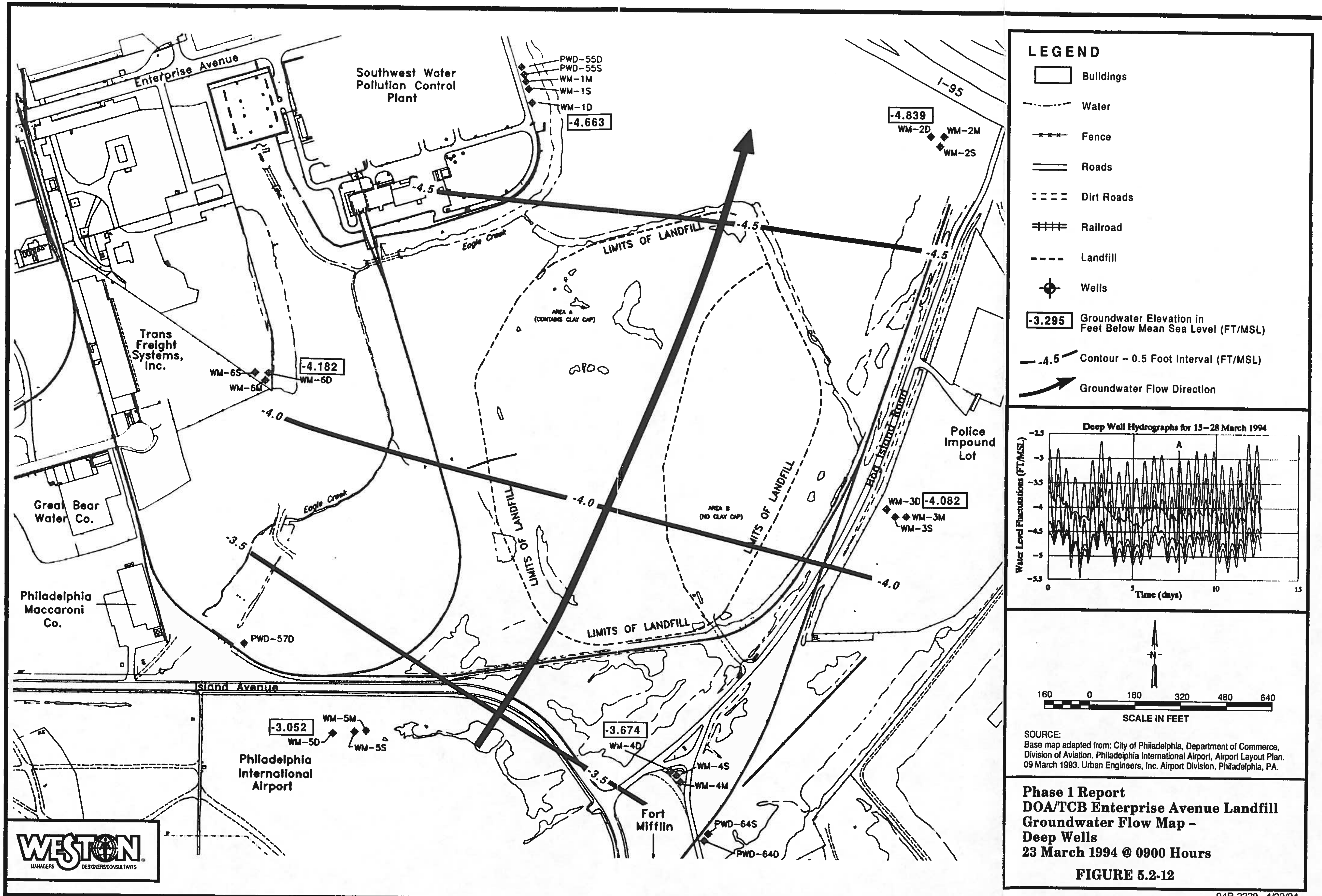
Horizontal gradients in the shallow water-bearing zone were not determined because of the localized groundwater flow conditions. Horizontal gradients in the intermediate and deep water-bearing zone were estimated based on water elevation data collected during 15 to 28 March 1994. Horizontal gradients in the intermediate zone were calculated using water elevation data collected from wells WM-5M and WM-6M, since these wells were most directly up-gradient and down-gradient from each other. Horizontal gradients in the intermediate water-bearing zone ranged from 0.0001 to 0.0005 feet/feet. Horizontal gradients for the deep water-bearing zone were calculated using water elevation data collected from wells 2D, 4D, and 6D since these wells represented up-gradient and down-gradient wells during each direction of groundwater flow. Horizontal gradients in the deep water-bearing zone ranged from 0.0001 to 0.0005 feet/feet.

To evaluate the vertical gradients present between both the shallow and intermediate and the intermediate and deep zones, a set of six hydrographs were constructed (Figure 5.2-17). Each hydrograph contains data for all three wells present at one well triplet location. These hydrographs exhibit the relationship of potentiometric heads in the three water-bearing units at one location. At location WM-1, the head in the shallow zone is always higher than the head in the intermediate zone which represents a downward gradient. The potentiometric head in WM-1M is generally lower than the potentiometric head in WM-1D, indicating an upward gradient from the deep zone to the intermediate zone. There are times when there is a reversal of vertical gradient between WM-1M and WM-1D to a downward direction. This change in vertical gradient occurs during tidal extremes (low tides).

At location WM-2, the vertical gradient is downward from WM-2S to WM-2M, as well as from WM-2M to WM-2D. This downward gradient is consistent through the entire data record.

The vertical gradient at WM-3 is also downward between the shallow and intermediate zones as well as between the intermediate and deep zones. This condition occurs throughout the monitored period.

At location WM-4, the vertical gradients are consistently downward from the shallow zone to the intermediate zone. The head in the intermediate zone is generally higher than the head in the deep zone. Although there are times when the heads are nearly equal. The gradient for the intermediate zone to the deep zone at location WM-4 varies from none to downward.

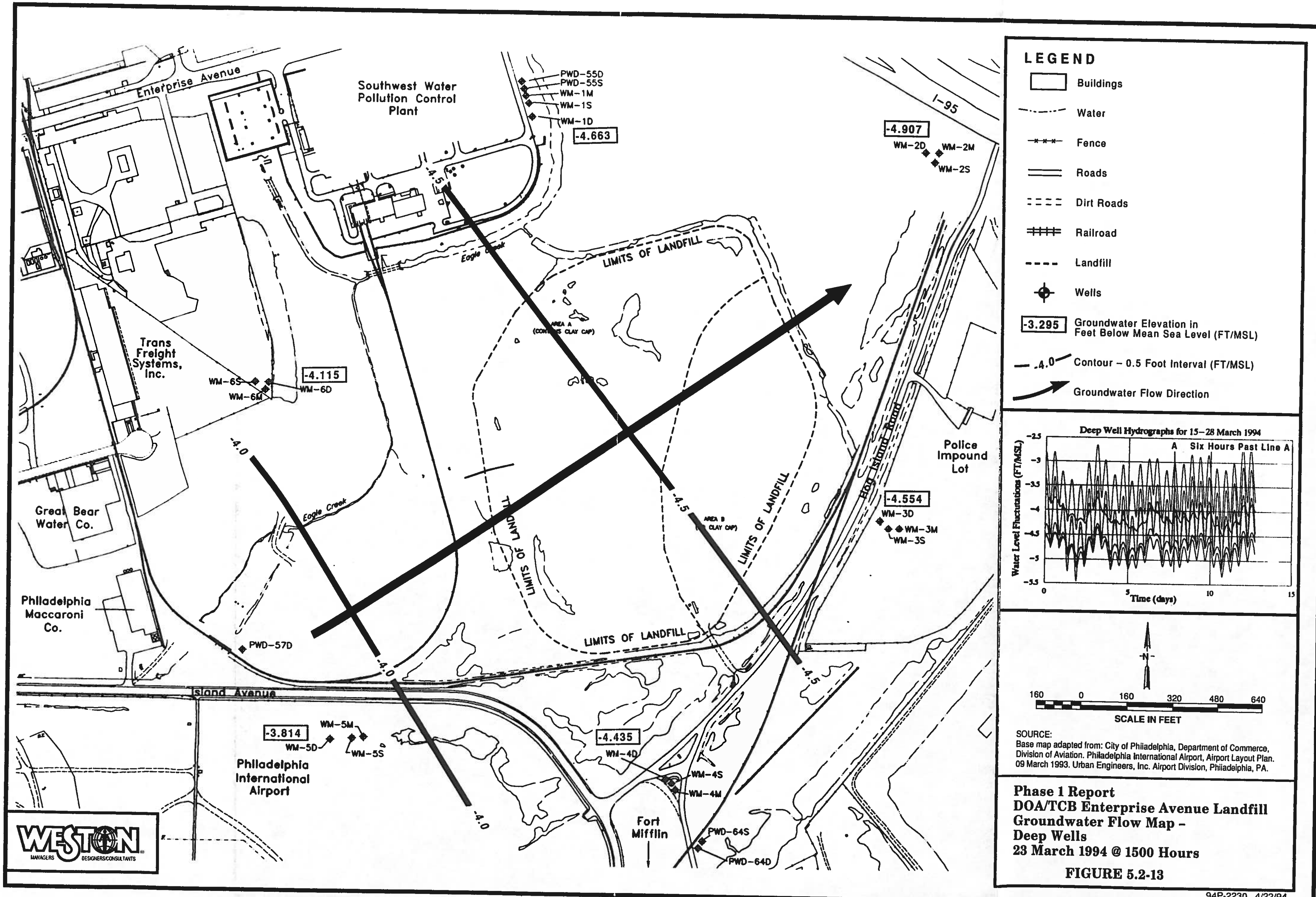


SOURCE:
Base map adapted from: City of Philadelphia, Department of Commerce, Division of Aviation. Philadelphia International Airport, Airport Layout Plan. 09 March 1993. Urban Engineers, Inc. Airport Division, Philadelphia, PA.

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Groundwater Flow Map –
Deep Wells
23 March 1994 @ 0900 Hours

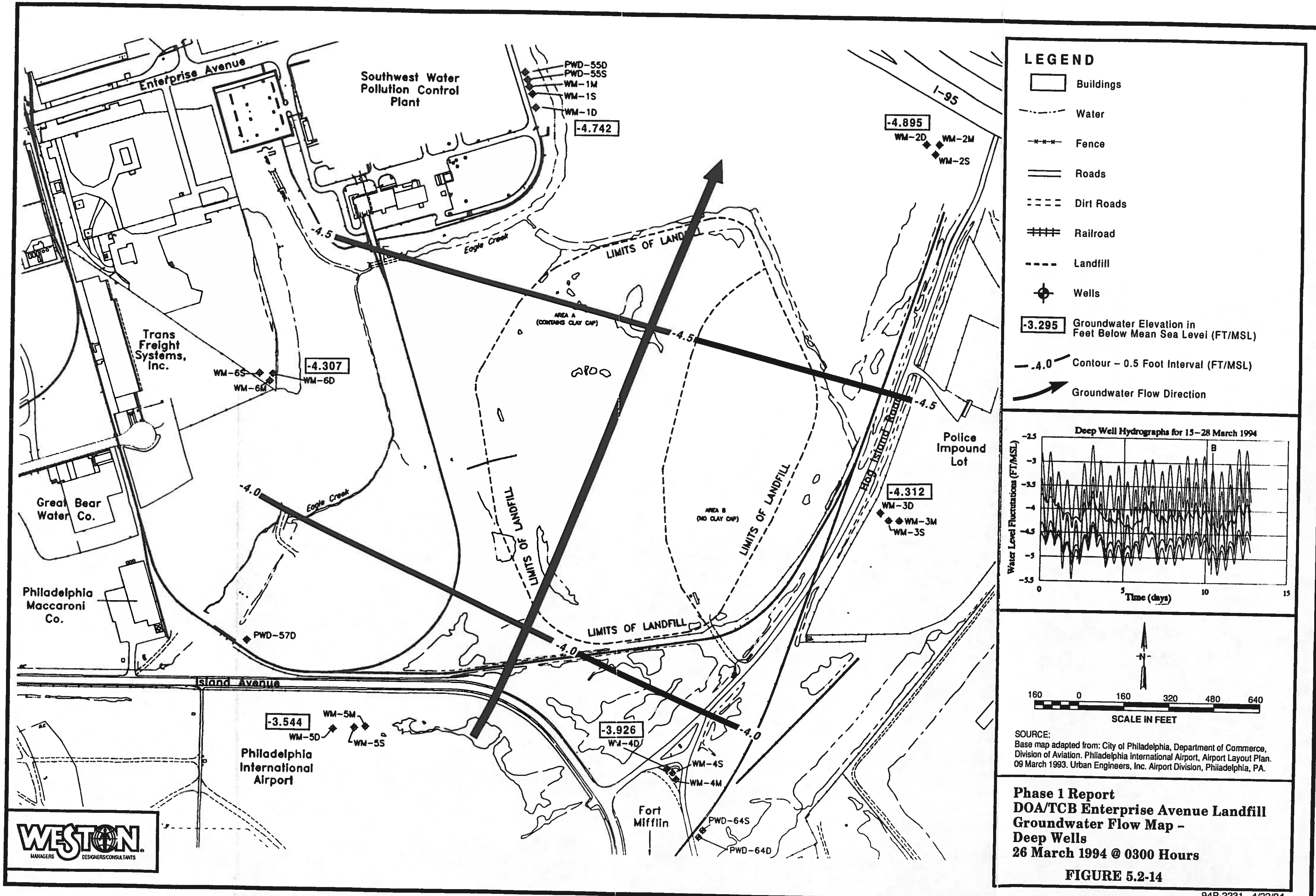
FIGURE 5.2-12

94P-2229 4/22/94



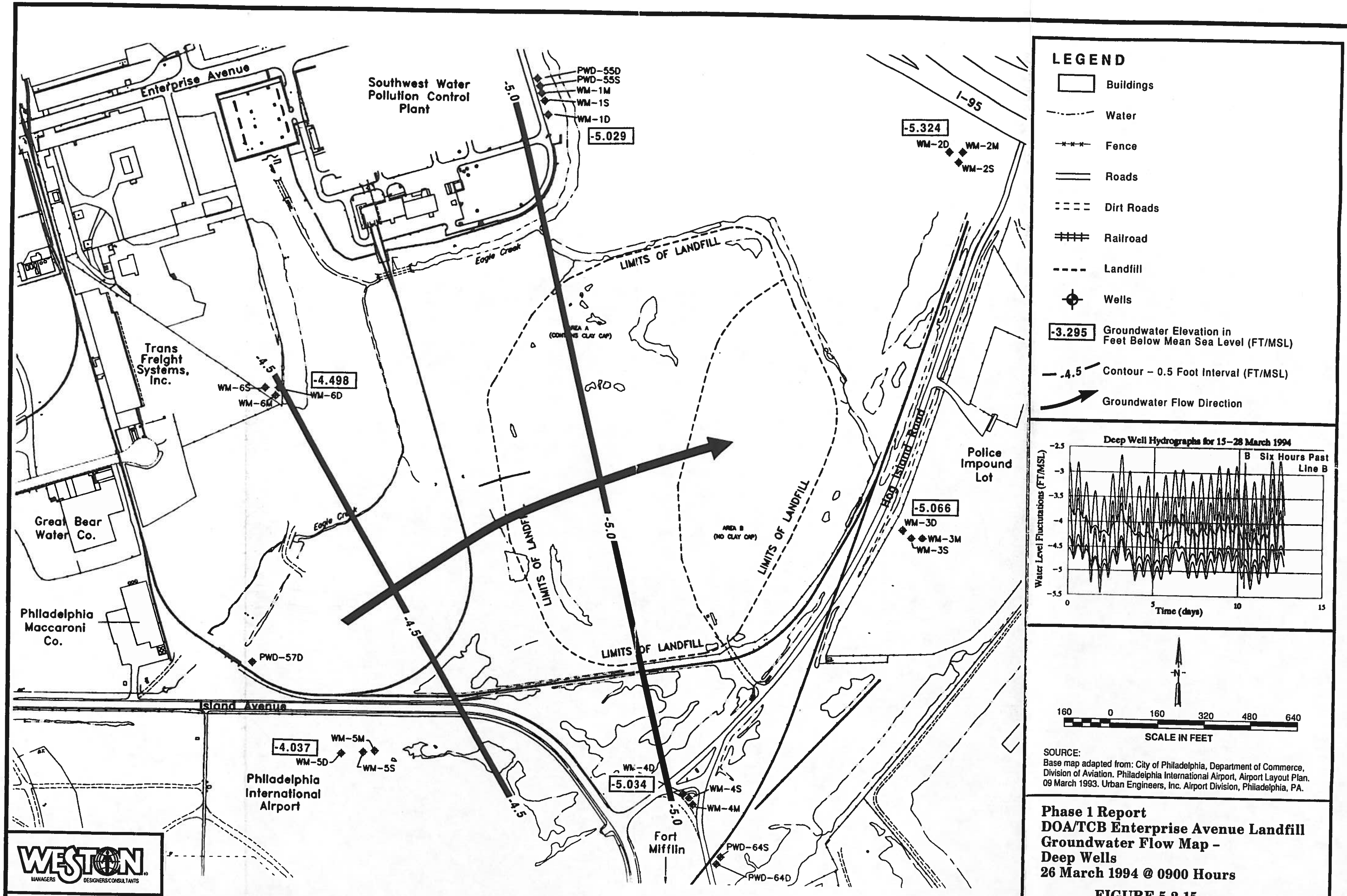
Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Groundwater Flow Map – Deep Wells
23 March 1994 @ 1500 Hours

FIGURE 5.2-13



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Groundwater Flow Map -
Deep Wells
26 March 1994 @ 0300 Hours

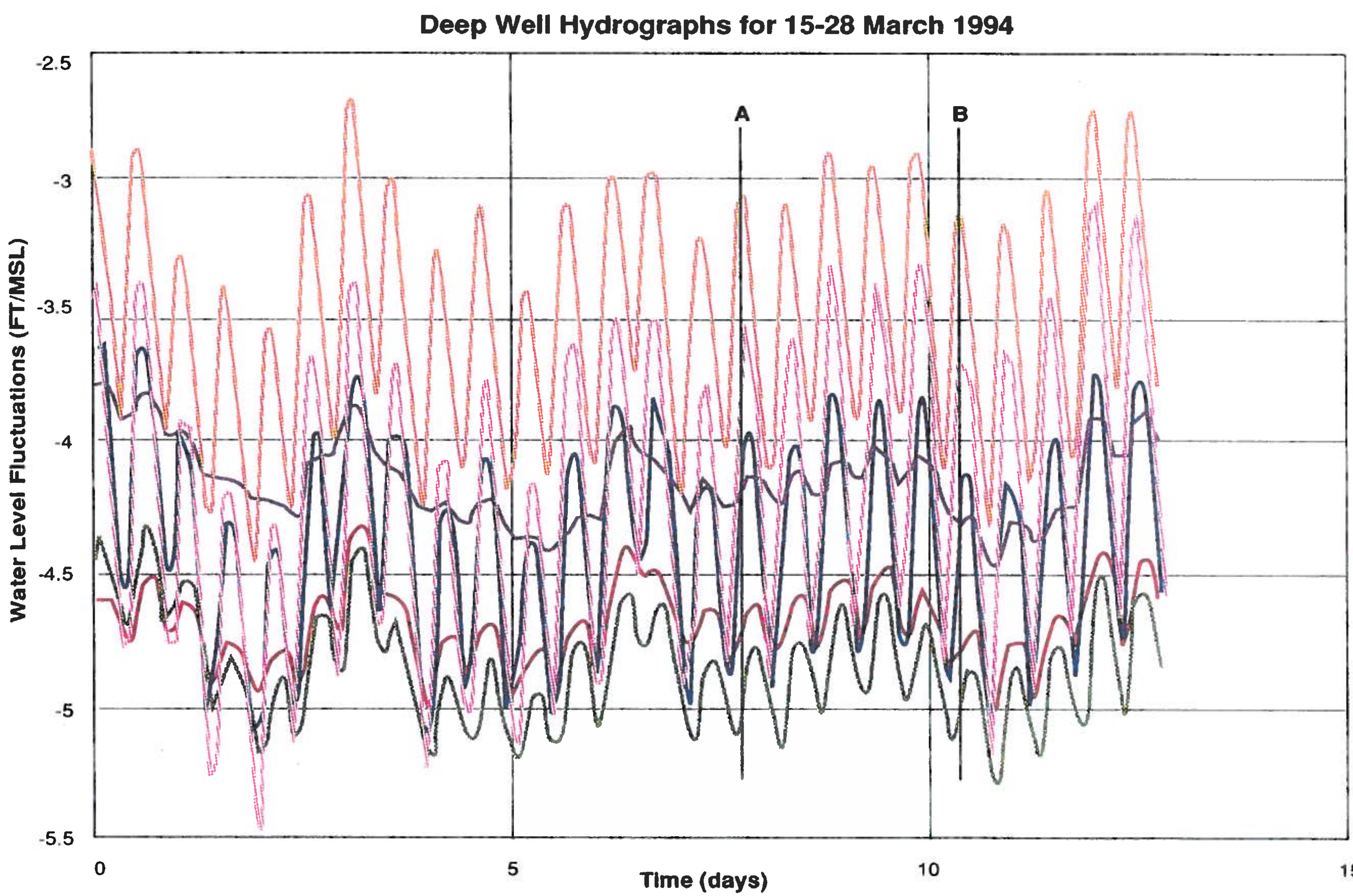
FIGURE 5.2-14



Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Groundwater Flow Map - Deep Wells
26 March 1994 @ 0900 Hours

FIGURE 5.2-15

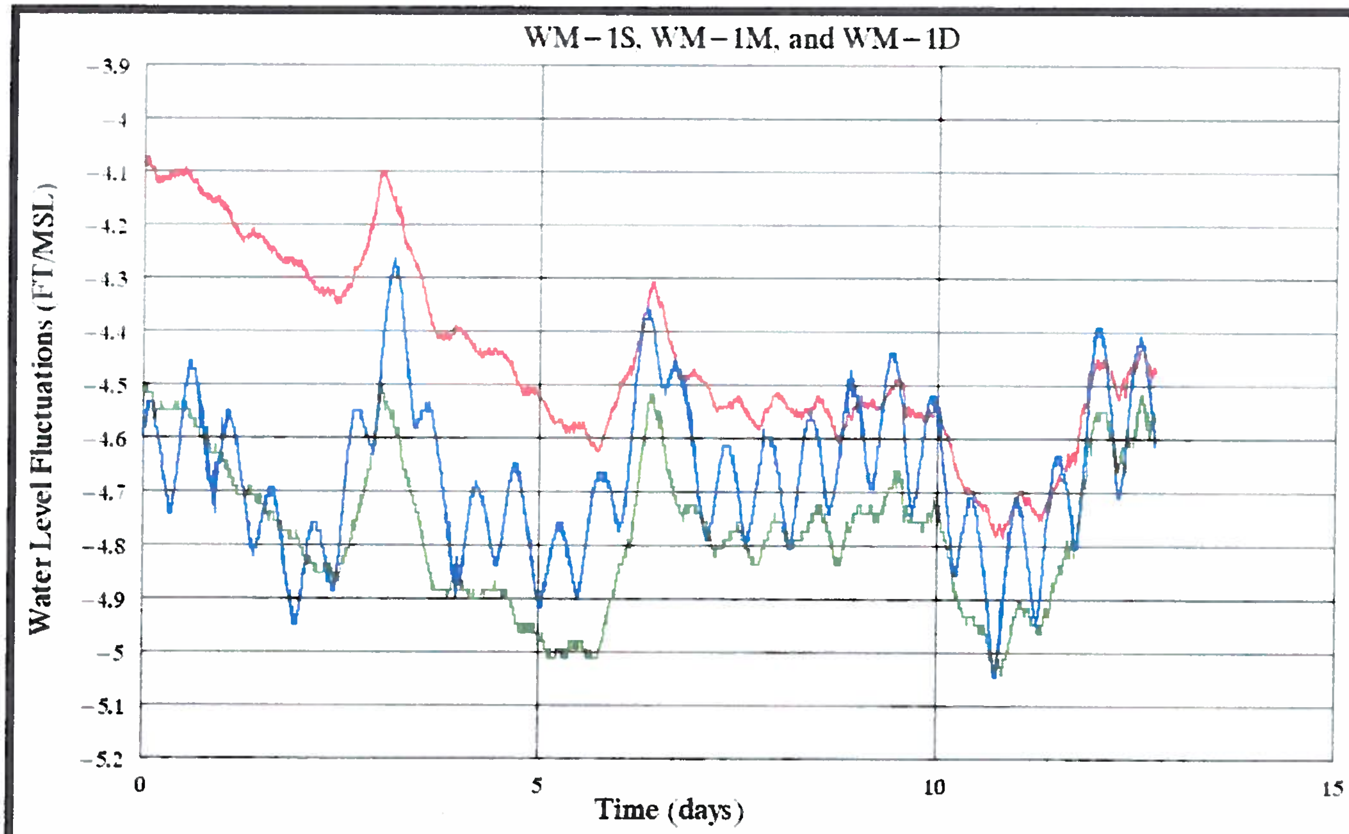
94P-2232 4/22/94

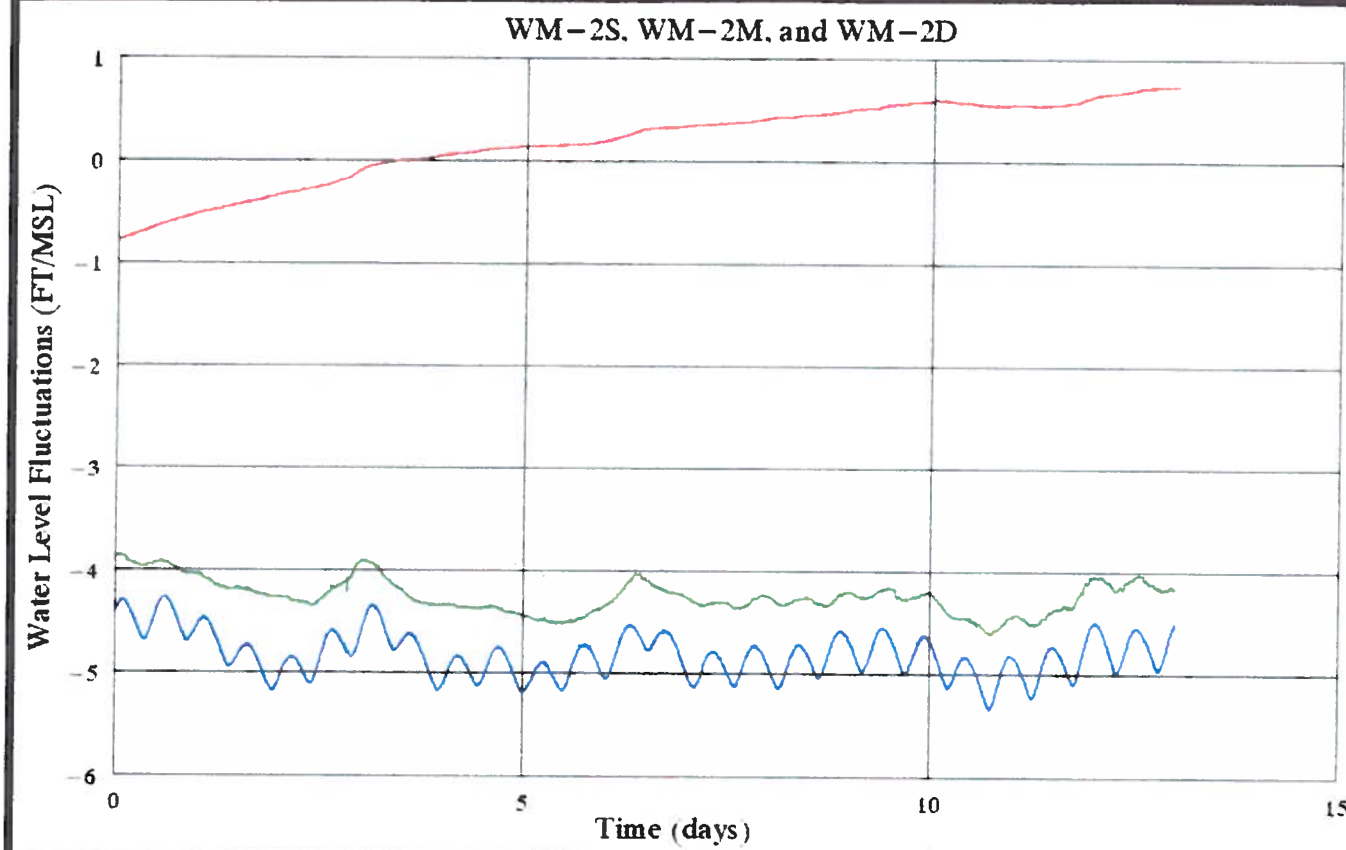


Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Hydrographs – Six Deep Wells
15 to 28-MAR-94

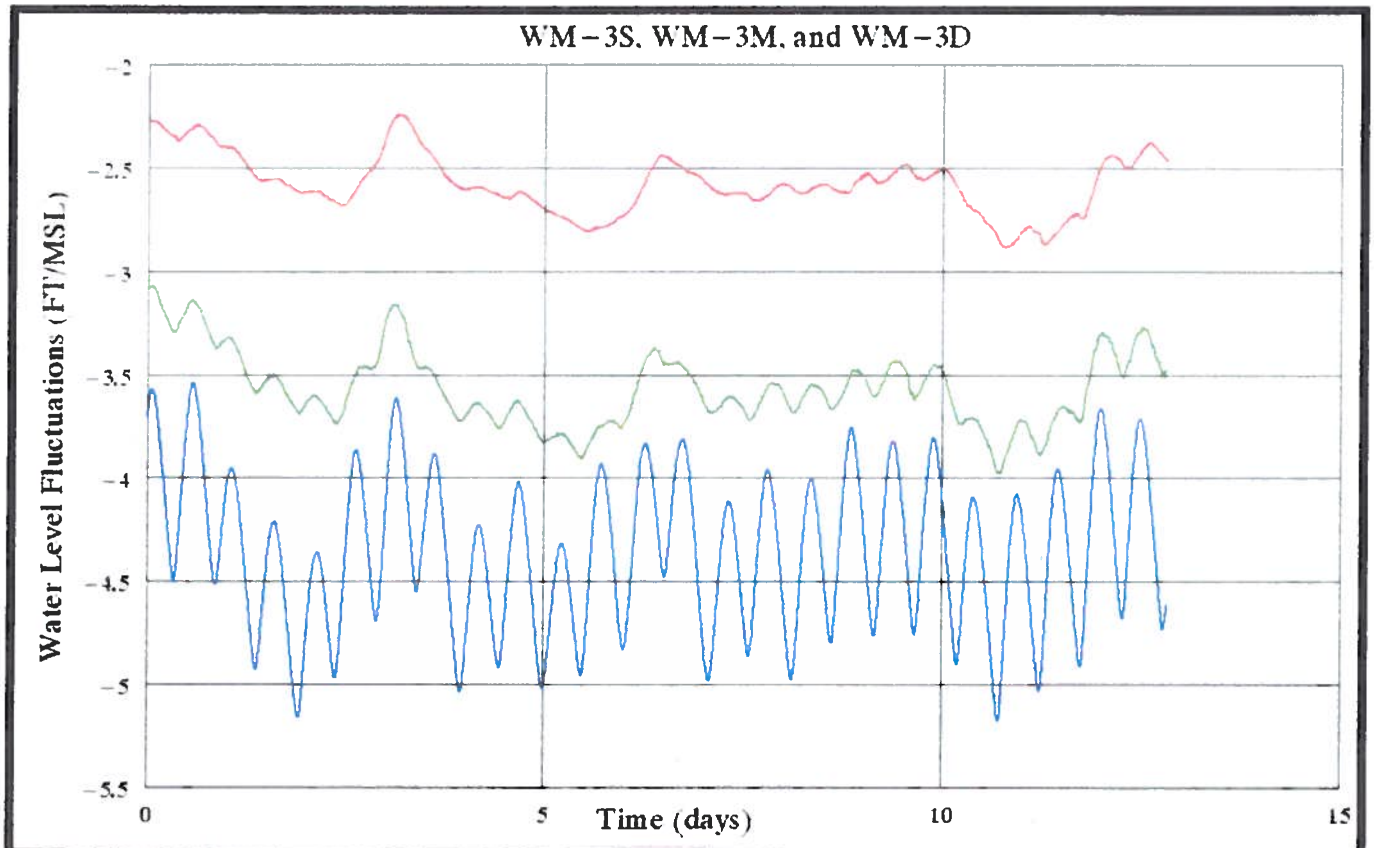
DRAFT FIGURE 5.2-16

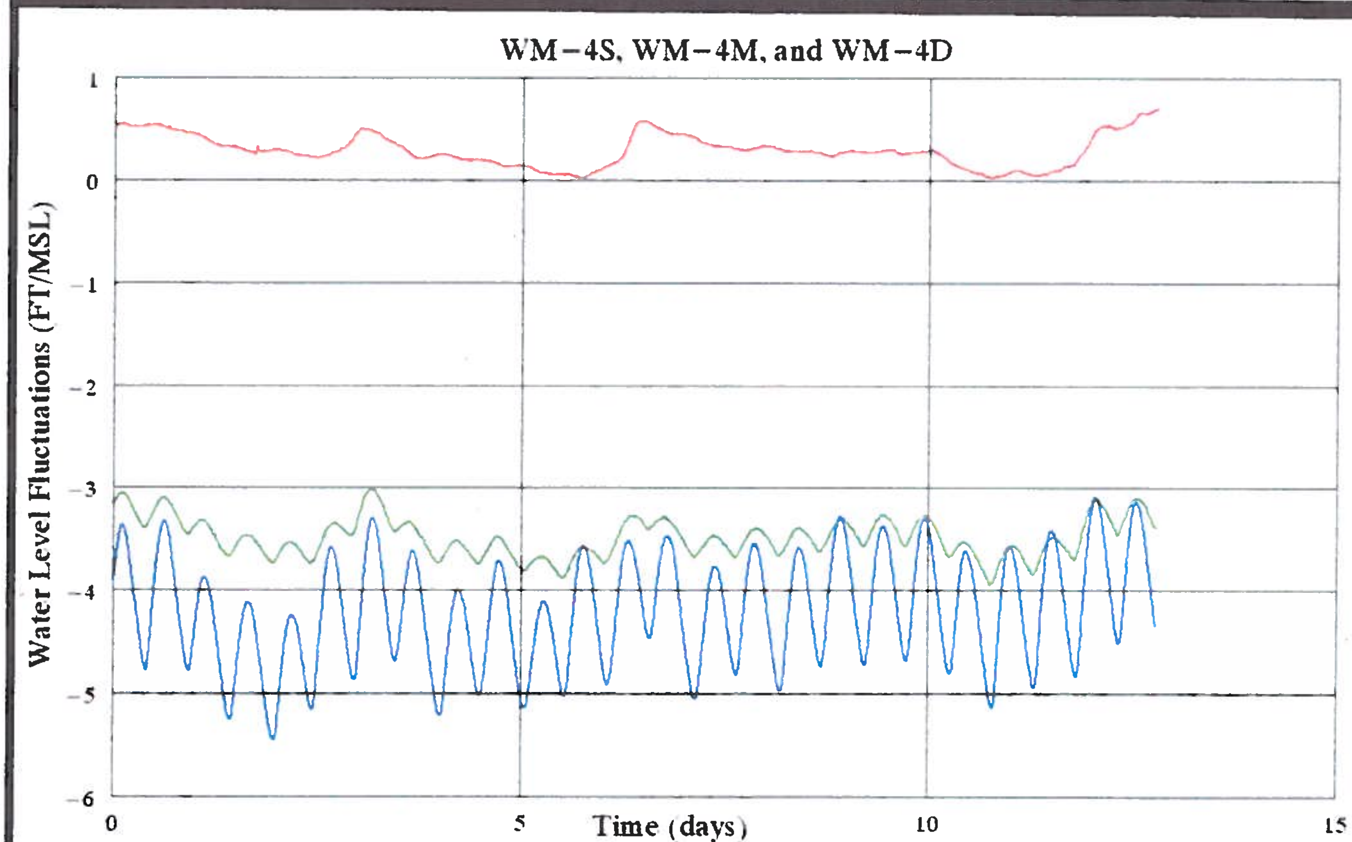
94P-2244





	LEGEND	
WESTON MANAGERS DESIGNERS CONSULTANTS	WM-1S WM-1M WM-1D WM-2S WM-2M WM-2D	**Phase 1 Report** **DOA/TCB Enterprise Avenue Landfill** **Vertical Gradients – Six Well Triplets and Well Pair PWD-55S/55D: 15 to 28-MAR-94** **DRAFT FIGURE 5.2-17**





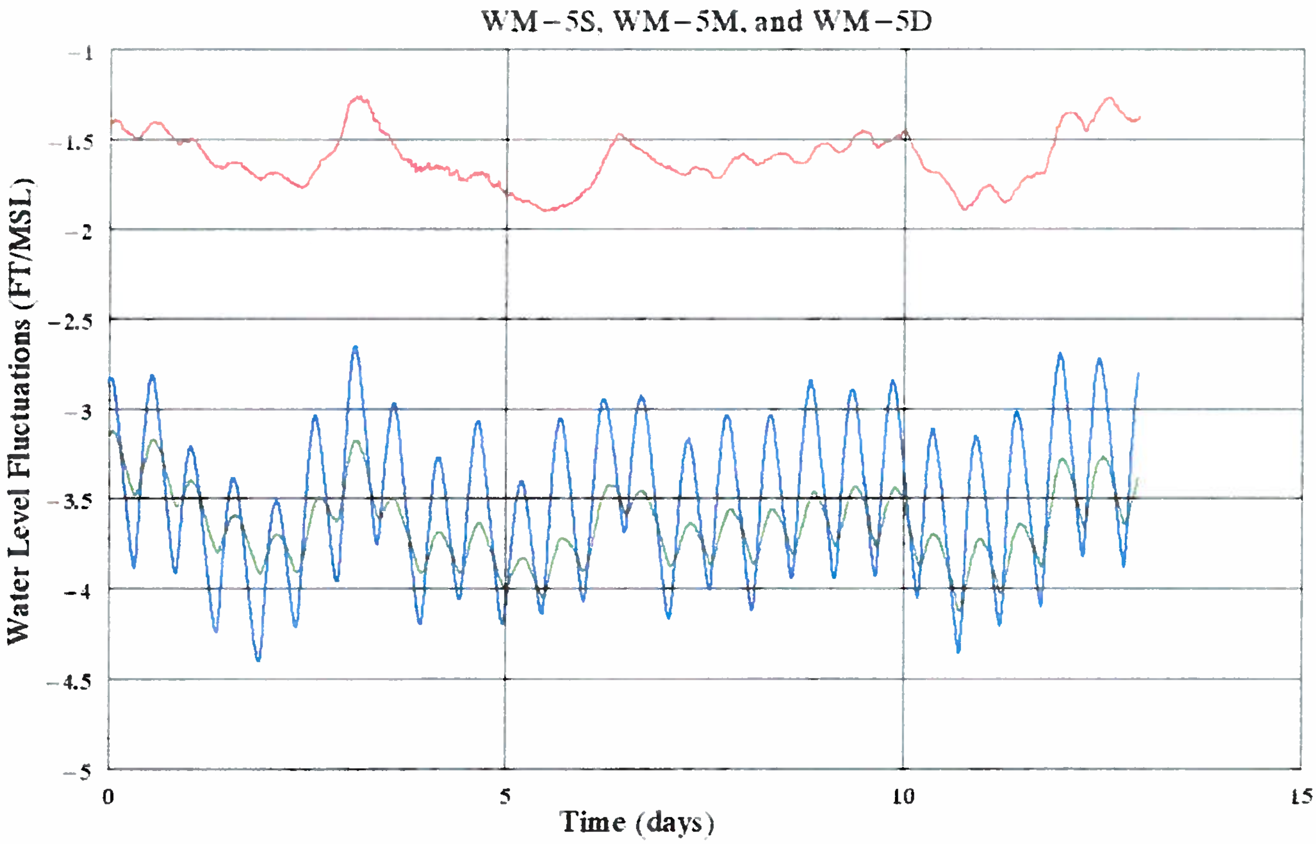
WESTON MANAGERS DESIGNERS/CONSULTANTS

LEGEND

WM – 3S WM – 4S
WM – 3M WM – 4M
WM – 3D WM – 4D

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Vertical Gradients – Six Well Triplets and Well Pair PWD-55S/55D: 15 to 28-MAR-94

DRAFT FIGURE 5.2-17, continued

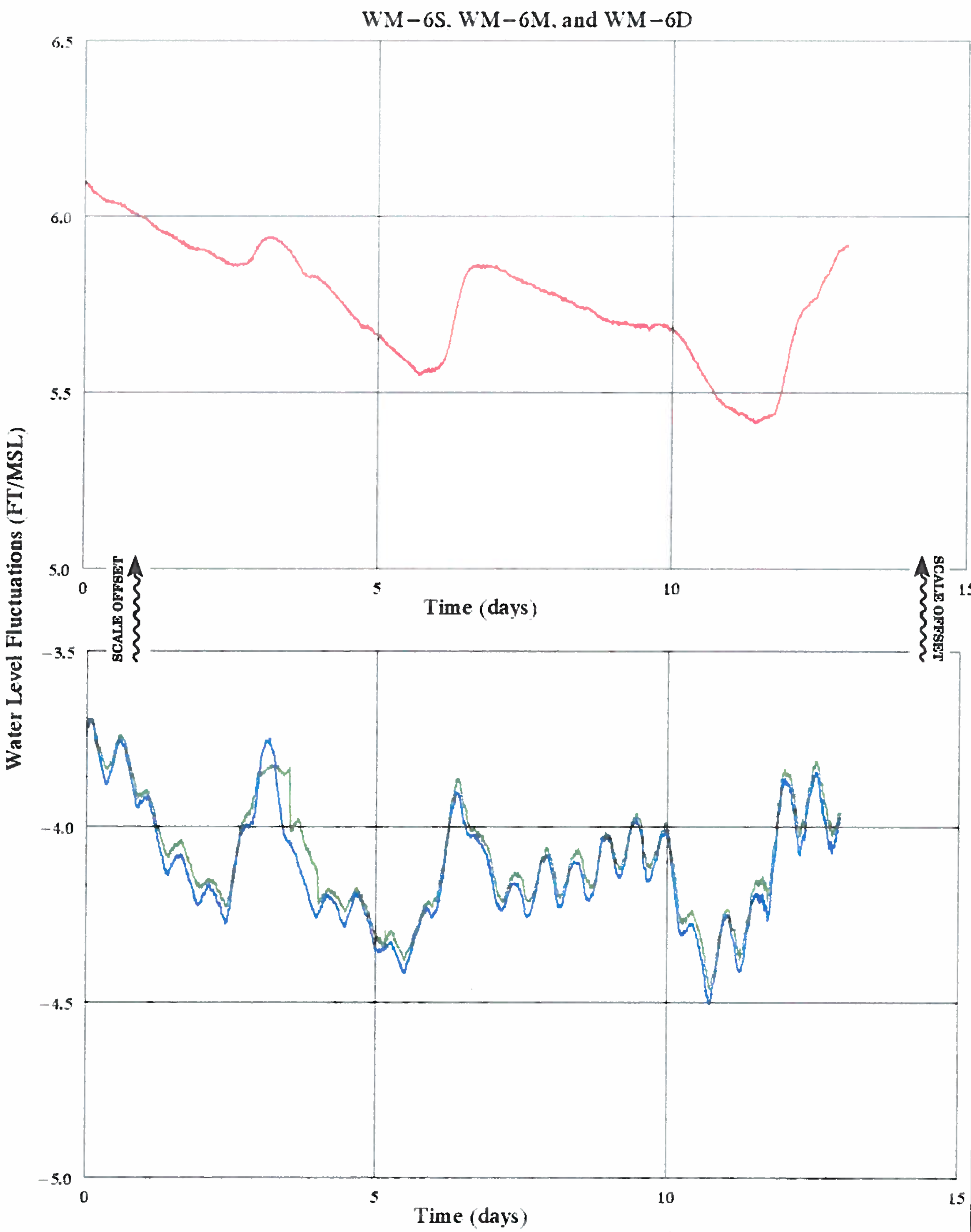


LEGEND
WM-5S
WM-5M
WM-5D

WESTON MANAGERS DESIGNERS/CONSULTANTS

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Vertical Gradients - Six Well Triplets and Well Pair PWD-55S/55D: 15 to 28-MAR-94
DRAFT FIGURE 5.2-17, continued

94P-2247



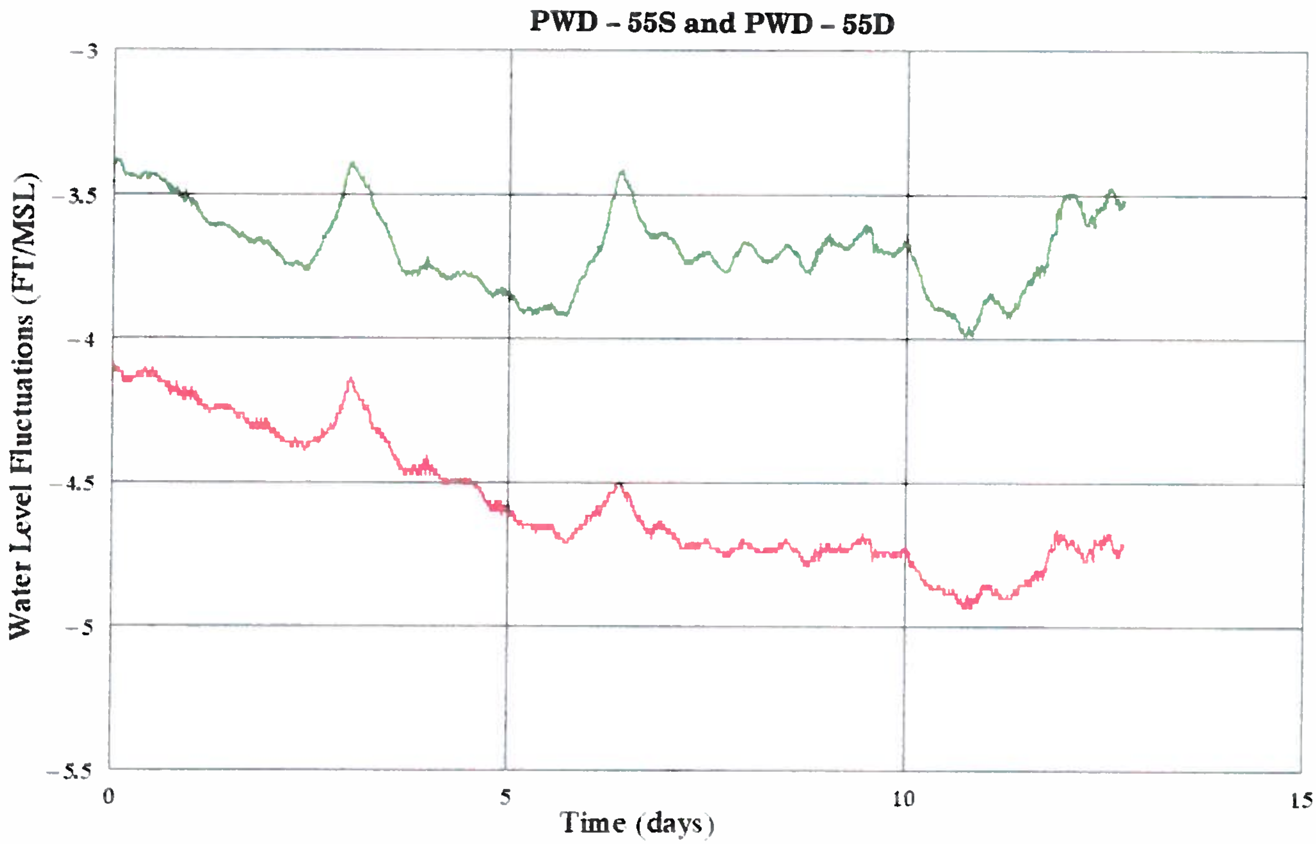
WESTON MANAGERS DESIGNERS CONSULTANTS

LEGEND

WM−6S
WM−6M
WM−6D

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Vertical Gradients – Six Well Triplets and Well Pair PWD-55S/55D: 15 to 28-MAR-94

DRAFT FIGURE 5.2-17, continued



WESTON MANAGERS DESIGNERS/CONSULTANTS

LEGEND

PWD – 55S

PWD – 55D

Phase 1 Report
DOA/TCB Enterprise Avenue Landfill
Vertical Gradients – Six Well Triplets and Well Pair PWD-55S/55D: 15 to 28-MAR-94

DRAFT FIGURE 5.2-17, continued

94P-2248

The heads in WM-5S are consistently higher than in WM-5M, indicating a consistent downward gradient between the shallow and intermediate zones. The heads in WM-5M are higher than in WM-5D only at the low points in the tidally induced head fluctuations. At the high points in the tidal head fluctuations, the head in WM-5D is actually higher than WM-5M. This indicates that the gradient changes from downward during the pg. 2 response to low tide to upward during the response to high tide. This variation is apparently the result of the greater potentiometric head response to tides exhibited by the deep zone. This greater response may be due to a higher aquifer efficiency.

At location WM-6, the heads in the shallow zone are consistently higher than those in the intermediate zone. This indicates a consistent downward gradient. The potentiometric heads in WM-6M and WM-6D are very similar; however, WM-6M is generally slightly higher. One time during the data record, the head in WM-6D exceeded that in MW-6M. The gradient for the intermediate to the deep zone at this location is slightly downward with one exception, when it was slightly upward.

Hydrographs for wells 55S and 55D were also examined. The head in 55S is consistently higher than head in 55D, which indicates a consistent downward gradient for the shallow zone to the intermediate zone at this location. This is consistent with the situation observed at location WM-1, which is nearby.

It is important to recognize that vertical gradients represent only differences in pressure head or potential between the water-bearing zones. The pressure of a gradient does not mean that there is any significant flow occurring. In fact, where substantial thicknesses of plastic clays exist between zones, it is likely that no significant groundwater movement is occurring between those zones.

5.2.5 Conclusions

The following discussion presents the conclusions on the site hydrogeology with respect to monitor well installation; groundwater levels; groundwater flow direction; and horizontal and vertical gradients for shallow, intermediate, and deep water-bearing zones at the EAL.

5.2.5.1 Shallow Water-bearing Zone

- All shallow wells were screened in the Qal layer with the exception of WM-1S which is screened in the sandy fill material.
- Groundwater levels in the shallow wells fluctuate in relation to changes in barometric pressure, as well as tidal pressures associated with the Delaware River.
- The direction of groundwater flow is dependent upon localized conditions at each well. WM-1S and WM-6S appear to be hydraulically connected to Eagle Creek. The probable direction of groundwater flow at WM-2S is southwesterly towards the EAL. The direction of groundwater flow at wells WM-3S, WM-4S, and WM-5S is uncertain due to the complexity of the shallow water-bearing zone flow regime.

5.2.5.2 Intermediate Water-bearing Zone

- Each of the intermediate wells are screened in the Qp layer.
- Groundwater levels in the intermediate wells fluctuate in relation to changes in barometric pressure, as well as tidal pressures associated with the Delaware River.
- The direction of groundwater flow in the intermediate zone during high and low tide cycles is northwesterly.
- Wells WM-3M and WM-4M are up-gradient; well WM-1M is down-gradient; wells WM-2M and WM-6M are cross-gradient of the EAL.
- The horizontal gradient ranges from 0.0001 to 0.0005 feet/feet. The vertical gradient is specific for each well location.

5.2.5.3 Deep Water-bearing Zone

- All deep wells were double cased and screened in the first sand and gravel layer encountered below the Kprm silty clay.

- Groundwater levels in the deep wells fluctuate in relation to changes in barometric pressure as well as tidal pressures associated with the Delaware River. Tidal fluctuations have the greatest influence on the deep wells.

- The prominent direction of groundwater flow is to the northeast and east. During low tides the direction of groundwater flow changes to the southeast.

- Wells WM-1D, WM-2D, and WM-3D are down-gradient; and wells WM-4D, WM-5D, and WM-6D are up-gradient of the EAL when the direction of groundwater flow is to the northeast and east. Wells WM-3D and WM-4D are down-gradient; and WM-1D and WM-6D are up-gradient during the brief transient groundwater flow direction change that occurs during occasional low tides when the direction of groundwater flow is to the east-southeast.

- The horizontal gradient for the deep water-bearing zone ranges from 0.0001 to 0.0005 feet/feet.

- The confining layer above the screened intervals of the deep wells is competent as shown by the different flow regimes in the deep and shallow intermediate water-bearing zones.

SECTION 6
GROUNDWATER QUALITY

6.1 INTRODUCTION

The following section presents the results of the first round of groundwater sampling conducted at EAL. The chain of custodies are presented in Appendix I, and the data summary reports are presented in Appendix J.

6.2 SHALLOW WATER-BEARING ZONE

The first round of groundwater samples was taken in all of the shallow wells from 2 to 9 March 1994. The field parameter data for the shallow wells are shown in Table 6.2-1. The pH in samples collected from the shallow wells ranged from 4.83 units in PWD-55S to 6.44 units in WM-3S. The average temperature was 12.9 degrees celsius. Specific conductivity ranged from 22 milliseimens/centimeter (mS/cm) in PWD-64S to 2008 mS/cm in WM-4S. The Eh of the groundwater ranged from -48 millivolts (mV) in WM-2S to 276 mV in WM-1S. Dissolved oxygen ranged from 0.91 mg/L in WM-6S to 7.10 mg/L in WM-2S. The specific conductivity, pH, Eh, and dissolved oxygen were within the same order of magnitude in wells WM-1S and PWD-55S. Specific conductivity in WM-4S was two orders of magnitude higher than well PWD-64S. Turbidity ranged from 3.1 NTUs in WM-2S to 46 NTUs in PWD-55S. Turbidity was extremely high and beyond the instruments range in a sample collected from well PWD-64S. This is due to the well going dry during sampling and therefore stirring up sediments from the bottom of the well.

A summary of organic and inorganic compounds detected in groundwater samples collected from the shallow wells is presented in Table 6.2-2. Low levels of volatile organic compounds (VOCs), including carbon disulfide, chlorobenzene, chloroform, dichlorobenzene, ethylbenzene, toluene, and xylene, were detected in samples collected from wells WM-1S, WM-2S, WM-3S, and WM-6S, with the majority of these compounds being detected in well WM-2S. Most of these compounds were detected at concentrations below the quantitation

Table 6.2-1

Enterprise Avenue Landfill
Summary of Physical Parameters in Groundwater
Collected During First Sampling Round

Well ID	Physical Parameters					
	Temp (C)	Specific Conductance (mS/cm)	pH (units)	Eh (mV)	Dissolved Oxygen (mg/L)	Turbidity (NTUs)
WM-1S	12.3	173	5.15	276	5.10	N/A
PWD-55S	12.8	219	4.83	146	4.32	46
WM-2S	14.6	1800	6.40	-48	7.10	3.1
WM-3S	13.5	2000	6.44	-121	1.82	8.8
WM-4S	11.9	2008	6.62	-96	2.43	32
PWD-64S	8.6	22	6.37	-87	N/A	>200
WM-5S	14.3	1237	6.23	-54	1.60	14
WM-6S	15.2	1022	6.62	-87	0.91	12
WM-1M	10.1	723	6.81	24	0.80	13
PWD-55D	13.4	562	4.04	-72	2.30	3.9
WM-2M	14.2	1150	6.57	-118	1.38	5.1
WM-3M	15.4	1351	6.54	-116	1.64	8
WM-4M	13.6	1120	6.70	-135	1.10	5.5
PWD-64D	13.9	1052	6.52	-106	1.78	6.4
WM-5M	14.9	789	7.13	-160	1.35	4.76
WM-6M	14.7	503	6.66	87	2.70	15
WM-1D	13.1	309	9.62	38	3.60	25
WM-2D	13.8	250	6.01	91	1.23	87.4
WM-3D	14.0	245	6.08	113	2.70	>200
WM-4D	13.2	286	6.76	27	1.88	>200
WM-5D	14.0	304	9.25	-76	9.00	>200
WM-6D	14.2	530	7.04	-444	1.71	51.1

C - Degrees Celsius.
mS/cm - Milliseimens/centimeter.
units - Standard pH units.
mV - Millivolts.

mg/L - Milligrams/Liter.
NTUs - National Turbidity Units.
>200 - Greater than instruments range.
NA - Not available.

Table 6.2–2

Enterprise Avenue Landfill
Summary of Organic and Inorganic Compounds Detected in Groundwater Samples Collected from Shallow Wells During the First Sampling Round

Well ID:	WM–1S	WM–2S	WM–3S	WM–4S	WM–5S	WM–6S	55S	64S
Volatile Organic Compounds (μg/L)								
Benzene	---	---	---	---	---	---	---	---
Bromodichloromethane	---	---	---	---	---	---	---	---
Carbon Disulfide	---	.5 J	---	---	---	3	---	---
Chlorobenzene	---	2	---	---	---	---	---	---
Chloroethane	---	---	---	---	---	---	---	---
Chloroform	.1 J	3	---	---	---	---	---	---
1,2–Dichlorobenzene	---	.1 J	---	---	---	---	---	---
1,3–Dichlorobenzene	---	---	---	---	---	---	---	---
1,4–Dichlorobenzene	---	.4 J	---	---	---	---	---	---
1,1–Dichloroethane	---	---	---	---	---	---	---	---
1,2–Dichloroethane	---	---	---	---	---	---	---	---
cis–1,2–Dichloroethene	---	---	---	---	---	---	---	---
trans–1,2–Dichloroethene	---	---	---	---	---	---	---	---
Ethylbenzene	---	.2 J	---	---	---	---	---	---
Toluene	.2 J	.5 J	---	---	---	---	---	---
1,1,1–Trichloroethane	---	---	---	---	---	---	---	---
Vinyl Chloride	---	---	---	---	---	---	---	---
Xylene	---	3	.2 J	---	---	---	---	---
Semivolatile Organic Compounds (μg/L)								
Bis(2–Ethylhexyl)Phthalate	---	---	---	---	---	---	---	96
4–Methylphenol	---	---	11	---	---	2 J	---	---
Pesticides (μg/L)	---	---	---	---	---	---	---	---
PCBs (μg/L)	---	---	---	---	---	---	---	---
Metals (Total) (μg/L)								
Aluminum	917	57.4 J	117 J	26.1 J	75.9 J	57.4 J	995	103000*
Antimony	---	---	---	---	---	---	---	---
Arsenic	---	6.3 J	11.3	8.5 J	11.4	14.4	---	75.0 J
Barium	60.5 J	432	500	368	464	109 J	35.6 J	1620 J
Beryllium	---	---	---	---	---	---	---	12.3
Cadmium	1.2 J	---	---	---	---	---	---	3.6 J

Table 6.2–2

Enterprise Avenue Landfill
Summary of Organic and Inorganic Compounds Detected in Groundwater Samples
Collected from Shallow Wells During the First Sampling Round

Well ID:	WM–1S	WM–2S	WM–3S	WM–4S	WM–5S	WM–6S	55S	64S
Metals (Total) (μg/L) (continued)								
Chromium	9.7 J	4.7 J	12.2	3.5 J	6.5 J	4.5 J	3.9 J	224
Cobalt	4.9 J	15.6 J	5.5 J	3.3 J	3.2 J	4.9 J	2.3 J	101 J
Copper	3.7 J	3.0 J	5.5 J	2.0 J	2.0 J	3.5 J	3.5 J	114 J
Iron	843	63400	56600	83000	98600	29100	394	270000*
Lead	1.2 J	–––	2.4 J	–––	–––	–––	–––	234
Manganese	315	10900	1560	14000	7530	2090	167	23800
Nickel	28.7 J	22.6 J	15.1 J	9.9 J	9.9 J	5.1 J	7.8 J	229 J
Selenium	–––	–––	–––	3.2 J	–––	–––	–––	6.2
Silver	–––	–––	–––	–––	–––	–––	–––	–––
Thallium	–––	–––	–––	–––	–––	–––	–––	1.0 J
Vanadium	1.0 J	1.5 J	2.0 J	1.2 J	2.2 J	1.4 J	1.6 J	143 J
Zinc	178	196	35.8	24.1	28.3	24.9	24.0	817
Calcium	20800	161000	174000	192000	173000	24800	20300	217000
Magnesium	4230 J	49600	76100	74500	64800	9520	4380 J	124000
Potassium	3740 J	7950	13900	5820	4060 J	28800	5850	29100
Sodium	4470 J	82800	31000	62600	19000	162000	4110 J	39300
Mercury	–––	–––	–––	–––	–––	–––	–––	0.89
Cyanide (ug/L)	–––	–––	–––	–––	–––	–––	–––	87.3
Total Dissolved Solids (mg/L)	119	1020	891	1060	1050	627	131	800

––– – Not detected above the instrument detection limit.
J – Estimated value detected below the quantification level.
*Presence of elemental interference during analysis.

limits and were therefore qualified with a "J" or estimated concentration. VOCs were not detected in samples collected from wells WM-4S, WM-5S, PWD-55S, or PWD-64S. Two semivolatile organic compounds (SVOCs) were detected in samples collected from the shallow wells. Bis(2-ethylhexyl)phthalate was detected at 96 μg/L in a sample collected from well PWD-64S, and 4-methylphenol was detected in samples collected from wells WM-3S and WM-6S, at 11 μg/L and 2 μg/L (estimated concentration), respectively. Pesticides and polychlorinated biphenyls (PCBs) were not detected in any of the samples collected from shallow wells.

Twenty-one metal species were detected in samples collected from the shallow wells. Highest levels were detected in a sample collected from PWD-64S at concentrations exceeding the Maximum Contaminant Limits (MCLs) as promulgated by the U.S. EPA. In this well arsenic was detected at 75 μg/L (estimated concentration), exceeding the MCL of 50 μg/L and beryllium was detected at 12.3 μg/L, exceeding the MCL of 4 μg/L. Chromium and lead were detected at 224 μg/L and 234 μg/L, exceeding MCLs of 100 and 15, respectively. Nickel was detected at 229 μg/L (estimated concentration), exceeding the MCL of 100 μg/L. The above listed metals identified in well PWD-64S at the concentrations detailed above may be influenced by the presence of elemental interference during the analysis of this sample and high turbidity in the sample during groundwater sampling.

Total dissolved solids (TDS) ranged from 119 mg/L to 1060 mg/L in wells WM-1S and WM-4S, respectively. Lowest concentrations of TDS were observed in samples collected from wells WM-1S and PWD-55S, which were screened in the sandy fill material. Cyanide was detected in well PWD-64S at 87.3 ug/L which is below the MCL of 200 μg/L.

In summary organic compounds were detected in samples collected from the shallow wells at low levels, all below Federally mandated MCLs. The majority of the VOCs were detected in WM-2S. This may be due to construction debris which was present at location WM-2 from the ground surface to approximately 12 feet BGS. There was also an odor present when drilling into the first ten feet of surface material. The concentrations of VOCs in samples collected from the shallow wells did not exceed MCL levels. Five metals were detected at concentrations above MCL levels in a sample collected from well PWD-64S. However these concentrations may be biased high due to elemental interferences during the analysis, and high turbidity encountered during sampling. Well PWD-64S is located potentially up-gradient of the EAL, and is screened at a shallower depth than other shallow wells. No other metals were detected above the MCL levels in the shallow wells.

The screened interval of this well is unknown, and the bottom of the well contains a silty material. The presence of silt in the preserved samples could contribute to the presence of the metals at these levels.

6.3 INTERMEDIATE WATER-BEARING ZONE

The intermediate wells were sampled during the same time period that the shallow wells were sampled. The field parameter data for the intermediate wells is shown in Table 6.2-1, the pH in samples collected from intermediate wells ranged from 4.04 units in well PWD-55D to 7.13 units in WM-5M. The average temperature was 13.8 degrees celsius. Specific conductivity ranged from well 503 mS/cm in WM-6M to 1351 well mS/cm in WM-3M. Eh ranged from -160 mV in well WM-5M to 87 mV in well WM-1S. Dissolved oxygen ranged from 0.80 mg/L in well WM-1M to 2.3 mg/L in well WM-6M. Turbidity ranged from 3.9 in well PWD-55D to 15 NTUs in well WM-6M.

A summary of organic and inorganic compounds detected in groundwater samples collected from the intermediate wells is presented in Table 6.3-1. SVOCs, pesticides, and PCBs were not detected in samples collected from the intermediate wells. The highest levels of VOCs were detected in samples collected from wells WM-1M and PWD-55D. Ten VOCs were detected in samples collected from wells WM-1M and PWD-55. Benzene, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, trans-1,2-dichlorobenzene, toluene, and vinyl chloride were detected in samples collected from both wells. In addition, chloromethane and xylene were detected in a sample collected from well WM-1M and 1,1-dichloroethane and cis-1,2-dichloroethene were detected in a sample collected from

Table 6.3–1

Enterprise Avenue Landfill
Summary of Organic and Inorganic Compounds Detected in Groundwater Samples Collected from Intermediate Wells During the First Sampling Round

Well ID:	WM–1M	WM–2M	WM–3M	WM–4M	WM–5M	WM–6M	55D	64D
Volatile Organic Compounds (μg/L)								
Benzene	32	– – –	– – –	– – –	– – –	– – –	1	– – –
Bromodichloromethane	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
Carbon Disulfide	– – –	– – –	– – –	– – –	.2 J	– – –	– – –	– – –
Chlorobenzene	300	– – –	– – –	– – –	– – –	– – –	95	– – –
Chloroethane	4	– – –	– – –	– – –	– – –	– – –	– – –	– – –
Chloroform	– – –	– – –	– – –	– – –	– – –	.2 J	– – –	– – –
1,2–Dichlorobenzene	32	– – –	– – –	– – –	– – –	– – –	18	– – –
1,3–Dichlorobenzene	9 J	– – –	– – –	– – –	– – –	– – –	4 J	– – –
1,4–Dichlorobenzene	78	– – –	– – –	– – –	– – –	– – –	29	– – –
1,1–Dichloroethane	– – –	– – –	– – –	– – –	– – –	– – –	.6 J	– – –
1,2–Dichloroethane	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
cis–1,2–Dichloroethene	– – –	– – –	.4 J	– – –	– – –	– – –	.2 J	– – –
trans–1,2–Dichloroethene	2	– – –	– – –	– – –	– – –	– – –	.5 J	– – –
Ethylbenzene	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
Toluene	2	– – –	– – –	– – –	– – –	– – –	.3 J	– – –
1,1,1–Trichloroethane	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
Vinyl Chloride	.8 J	– – –	2	– – –	– – –	– – –	.9 J	– – –
Xylene	3	– – –	– – –	– – –	– – –	– – –	– – –	– – –
Semivolatile Organic Compounds (μg/L)								
Bis(2–Ethylhexyl)Phthalate	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
4–Methylphenol	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
Pesticides (μg/L)	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
PCBs (μg/L)	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
Metals (Total) (μg/L)								
Aluminum	156 J	14.3 J	98.4 J	19.5 J	33.9 J	48.5 J	11.4 J	19.7 J
Antimony	– – –	– – –	4.5 J	– – –	– – –	– – –	– – –	– – –
Arsenic	7.2 J	27.5	7.9 J	103	56.2	28.4	12.0	12.1
Barium	452	1360	603	967	699	382	287	237
Beryllium	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –
Cadmium	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –

Table 6.3–1

Enterprise Avenue Landfill
Summary of Organic and Inorganic Compounds Detected in Groundwater Samples Collected from Intermediate Wells During the First Sampling Round

Well ID:	WM–1M	WM–2M	WM–3M	WM–4M	WM–5M	WM–6M	55D	64D
Metals (Total) (μg/L) (continued)								
Chromium	2.2 J	3.3 J	5.9 J	2.3 J	2.3 J	7.6 J	1.4 J	3.7 J
Cobalt	2.2 J	9.2 J	2.9 J	8.1 J	3.4 J	2.5 J	11.7 J	1.7 J
Copper	4.5 J	1.8 J	2.1 J	1.3 J	1.6 J	2.9 J	1.7 J	1.2 J
Iron	51600	79400	52300	56800	24600	34700	36300	26200
Lead	2.0 J	---	---	---	---	---	---	---
Manganese	7730	1950	598	177	332	789	7520	857
Nickel	3.9 J	7.3 J	7.1 J	10.2 J	4.4 J	16.3 J	5.2 J	11.8 J
Selenium	---	---	---	---	---	---	---	---
Silver	---	---	---	---	---	---	---	---
Thallium	---	---	---	---	---	---	---	---
Vanadium	1.1 J	1.6 J	3.4 J	---	---	---	---	1.3 J
Zinc	23.3	9.3 J	32.0	18.2 J	18.9 J	48.7	7.6 J	11.9 J
Calcium	39300	88300	107000	73100	39500	26300	31100	79300
Magnesium	22500	41700	51500	39000	34600	15800	15100	30500
Potassium	3310 J	4270 J	7570	6620	5130	2940 J	2810 J	7420
Sodium	67800	18600	21500	21400	20200	23300	41700	26000
Mercury	---	---	---	---	---	---	---	---
Cyanide (ug/L)	---	---	---	---	---	---	---	51.0
Total Dissolved Solids (mg/L)	422	492	605	429	336	271	328	485

--- – Not Detected Above the Contract Reporting Detection Limit (CRDL).
J – Estimated value detected below CRDL.

well PWD-55D. VOCs concentrations only exceeded the MCL levels in well WM-1M. Benzene was detected at 32 μg/L exceeding the MCL of 5 μg/L and 1,4-dichlorobenzene was detected at 78 μg/L exceeding the MCL of 75 μg/L in well WM-1M. Cis-1,2-dichloroethane and vinyl chloride were detected in samples collected from well WM-3M. Vinyl chloride was detected at the MCL level of 2 μg/L. Low levels of chlorobenzene and chloroform were detected in samples collected from wells WM-5M and WM-6M, respectively.

A comparison of the relative percentages of the VOCs appearing in each of these two wells (WM-1M and PWD-55D) was made since each of these wells is screened at approximately the same depth, and similar compounds were detected in each well. This comparison was made by generating the sum concentration of all VOCs detected in each of the two wells. The relative percentages of each of the compounds detected to the total VOC concentration in the well was then calculated. These percentages for the two wells were then compared. There was general agreement in the relative percentages of each compound observed in each of the wells. The presence of higher concentrations of VOCs in well WM-1M when compared to well PWD-55D may be related to differences in well efficiency and well screening interval.

Sampling data from 1985 through 1987 for the existing wells PWD-55D, PWD-55S, PWD-64D, and PWD-64S were examined to determine if conditions had changed in these wells since that time. It is important to note that sampling and analysis methods used during the 1985 through 1987 period are not directly comparable to the current method of sampling methodology. For each of these wells, the compounds detected in 1985 through 1987 are similar to the compounds detected in this round of sampling. Where differences exist (e.g., benzene in PWD-55D during the current round of sampling verses not detected in the historical data), higher laboratory detection limits utilized during the historic sampling events appear to be responsible.

Seventeen metal species were detected in samples collected from the intermediate wells. Arsenic was detected above the MCL of 50 μg/L in wells WM-4M and WM-5M at 103 μg/L and 56.2 μg/L, respectively.

TDS in samples collected from the intermediate wells ranged from 271 mg/L to 605 mg/L in wells WM-6M and WM-3M, respectively. Cyanide was only detected in a sample collected from well PWD-64D at a concentration of 51.0 μg/L, well below the MCL of 200 μg/L. Total dissolved solids ranged from 271 mg/L in well WM-6M to 605 mg/L in well WM-3M.

In summary, several VOCs were detected in wells WM-1M and PWD-55D. Benzene and 1,4-dichlorobenzene were the only VOCs detected above the MCLs for these compounds. Wells WM-1M and PWD-55D are potentially down-gradient of the EAL, however the influence of other sources of these compounds such as the adjacent Eagle Creek cannot be ruled out. Of the 17 metal species that were detected in groundwater samples collected from the intermediate wells, arsenic was the only metal detected above the MCL level in samples collected from wells WM-4M and WM-5M. Wells WM-4M and WM-5M are up-gradient of the EAL.

6.4 DEEP WATER-BEARING ZONE

The field parameter data for the deep wells are shown in Table 6.2-1. The pH in samples collected from the deep wells ranged from 6.01 units in well WM-2D to 9.62 units in well WM-1D. The average groundwater temperature for these wells was 13.7 degrees celsius. Specific conductivity ranged from 245 mS/cm in well WM-3D to 1530 mS/cm in well WM-6D. Eh ranged from -444 mv in well WM-6D to 113 mv in well WM-3D. Dissolved oxygen ranged from 1.23 mg/L in well WM-2D to 9.0 mg/L in well WM-5D. Values measured for specific conductivity, pH, and dissolved oxygen were within the same order of magnitude in all deep wells. Turbidity ranged from 25 in well WM-1D to >200 NTUs in wells WM-2D, WM-3D, and WM-4D. High turbidity levels in these three wells is due to suspended silt and clay sediments.

A summary of the organic and inorganic compounds detected groundwater samples collected from the deep wells is presented in Table 6.4-1. Low levels of bromodichloromethane, chloroform, toluene, and 1,1,1-trichloroethane were detected in samples collected from the

Table 6.4−1

Enterprise Avenue Landfill
Summary of Organic and Inorganic Compounds Detected in Groundwater Samples Collected from Deep Wells During the First Sampling Round

Well ID:	WM−1D	WM−2D	WM−3D	WM−4D	WM−5D	WM−6D
Volatile Organic Compounds (μg/L)						
Benzene	---	---	---	---	---	---
Bromodichloromethane	.3 J	.1 J	---	.2 J	---	---
Carbon Disulfide	---	---	---	---	---	---
Chlorobenzene	---	---	---	---	---	---
Chloroethane	---	---	---	---	---	---
Chloroform	.6 J	1	.3 J	1.0	.5 J	.4 J
1,2−Dichlorobenzene	---	---	---	---	---	---
1,3−Dichlorobenzene	---	---	---	---	---	---
1,4−Dichlorobenzene	---	---	---	---	---	---
1,1−Dichloroethane	---	---	---	---	---	---
1,2−Dichloroethane	---	---	---	---	---	---
cis−1,2−Dichloroethene	---	---	---	---	---	---
trans−1,2−Dichloroethene	---	---	---	---	---	---
Ethylbenzene	---	---	---	---	---	---
Toluene	.1 J	---	---	---	---	---
1,1,1−Trichloroethane	---	.1 J	.2 J	---	---	---
Vinyl Chloride	---	---	---	---	---	---
Xylene	---	---	---	---	---	---
Semivolatile Organic Compounds (μg/L)						
Bis(2−Ethylhexyl)Phthalate	---	---	---	---	---	---
4−Methylphenol	---	---	---	---	---	---
Pesticides (μg/L)	---	---	---	---	---	---
PCBs (μg/L)	---	---	---	---	---	---
Metals (Total) (μg/L)						
Aluminum	90.1 J	318	1230	6380	1510	400*
Antimony	---	---	---	---	---	---
Arsenic	2.9 J	---	---	---	2.9 J	3.5 J
Barium	23.5 J	47.6 J	48.4 J	99.6 J	25.1 J	59.7 J
Beryllium	---	---	2.6 J	5.2	---	---
Cadmium	---	---	---	---	---	---

Table 6.4–1

Enterprise Avenue Landfill
Summary of Organic and Inorganic Compounds Detected in Groundwater Samples Collected from Deep Wells During the First Sampling Round

Well ID:	WM–1D	WM–2D	WM–3D	WM–4D	WM–5D	WM–6D
Metals (Total) (μg/L) (continued)						
Chromium	5.1 J	5.5 J	11.7	19.5	18.5	7.4 J
Cobalt	–––	9.9 J	8.3 J	9.0 J	2.1 J	4.4 J
Copper	5.5 J	17.4 J	33.9	80.7	9.8 J	4.7 J
Iron	286	420	1410	5190	1110	723
Lead	1.5 J	1.1 J	6.7	9.2	2.0 J	–––
Manganese	8.5 J	107	54.7	112	13.4 J	1720
Nickel	3.9 J	12.8 J	19.3 J	33.6 J	8.9 J	9.6 J
Selenium	–––	–––	–––	–––	–––	–––
Silver	–––	–––	–––	–––	–––	–––
Thallium	–––	–––	–––	–––	–––	–––
Vanadium	47.7 J	2.9 J	18.7 J	24.0 J	38.9 J	24.3 J
Zinc	49.8	72.6	64.9	261	22.4	29.2
Calcium	40100	17800	13600	22900	30000	50400
Magnesium	5160	5000	4650 J	5290	2710 J	16200
Potassium	3540 J	2740 J	3020 J	3750 J	3940 J	4110 J
Sodium	22300	24200	34900	37800	32700	31000
Mercury	–––	–––	–––	–––	–––	–––
Cyanide (ug/L)	–––	–––	–––	–––	–––	–––
Total Dissolved Solids (mg/L)	195	152	244	231	178	274

–––– – Not Detected Above the Contract Reporting Detection Limit (CRDL).
J – Estimated value detected below CRDL.
*Presence of elemental interference during analysis.

concentrations. VOCs were not detected at concentrations exceeding MCL levels. SVOCs, deep wells. Most of the organic compounds were detected at "J" value or estimated pesticides, and PCBs were not detected in samples collected from the deep wells.

Sixteen metals species were detected in samples collected from the deep wells. Only beryllium was detected above the MCL level of 4 µg/L at 5.2 µg/L in a sample collected from well WM-4D. Heavy mineral species, such as beryl, that are present in the Kprm sediments could be a possible source of this compound. Cyanide was not detected in samples collected from the deep wells. Dissolved solids ranged from 152 mg/L in well WM-2D to 274 mg/L in well WM-6D.

In summary, only a few organic compounds were detected at low levels for the most part below the quantification level, and all are below MCLs in samples collected from the deep wells. Beryllium was the only metal detected in a sample collected from well WM-4D at concentrations exceeding the MCL level, but only slightly above the MCL. The source of this material could be related to heavy minerals naturally occurring in the Kprm sediments.

6.5 <u>CONCLUSIONS</u>

The following discussion presents the conclusions on the groundwater quality in the shallow, intermediate, and deep water-bearing zones at the EAL.

6.5.1 <u>Shallow Water-bearing Zone</u>

- Organic compounds were detected in samples collected from shallow wells at low levels, all below Federally mandated MCLs.
- Five metal species were detected at concentrations above MCL levels in a sample collected from well PWD-64S. However these concentrations may be biased high due to elemental interferences during the analysis, and high turbidity encountered during sampling.

6.5.2 Intermediate Water-bearing Zone

- Benzene and 1,4-dichlorobenzene were the only VOCs detected above the MCLs for these compounds. Wells WM-1M and PWD-55D are potentially down-gradient of the EAL, however the influence of other potential sources of these compounds such as Eagle Creek cannot be ruled out.

- Arsenic was the only metal detected above the MCL level in samples collected from wells WM-4M and WM-5M. Wells WM-4M and WM-5M are up-gradient of the EAL.

6.5.3 Deep Water-bearing Zone

- Few organic compounds were detected at low levels, and most of these organic compounds were detected below method quantification level. All are detected below the MCL level, in samples collected from the deep wells.

- Beryllium was the only metal detected in a sample collected from well WM-4D at concentrations exceeding the MCL level, but only slightly above the MCL.

SECTION 7
CONCLUSIONS

7.1 INTRODUCTION

This section of the report presents the conclusions of the Phase I Hydrogeologic Investigation at the EAL.

7.2 SITE GEOLOGY

During the Phase I field investigation four overburden units were encountered at EAL. These units were identified based on lithological and geophysical data collected during the installation of the six well triplets. The four overburden units are presented as follows:

- Fill Material
- Quarternary Age alluvium (Qal)
- Pleistocene Age sands and gravels (Qp)
- Cretaceous Age interbedded sands and gravels with silts and clays of the Potomac-Raritan-Magothy Formation (Kprm)

The overburden units are presented in the order as they appear in the stratigraphic column. and are discussed in detail in Section 4. Groundwater monitor wells were located in the units discussed above as follows:

- <u>Shallow Wells</u> — The shallow wells were screened in the saturated silt and clays of the Qal unit. At two of the locations, the screened interval extended into the overlying fill material.
- <u>Intermediate Wells</u> — The intermediate wells were screened in saturated sands and gravels of the Qp unit.
- <u>Deep Wells</u> — The deep wells were screened in saturated sands and gravels of the Kprm formation (MCA) below the silty clays of the Kprm (MCU)

formation. These silty clays are from 14 to 60 feet thick above the screened interval of the deep wells.

7.3 SITE HYDROGEOLOGY

7.3.1 Groundwater Levels

- Groundwater levels in the shallow, intermediate, and deep wells are influenced by barometric pressure, tides, and tidal pressure associated with the Delaware River.

- The largest tidal affects were observed in deep wells WM-3D, WM-4D, and WM-5D, which are closest to the river.

7.3.2 Groundwater Flow

- The direction of groundwater flow in the shallow water-bearing zone is uncertain due to locally variable and complex groundwater flow conditions due to the estuarine origin and other geomorphological variation of the sediments.

- The direction of groundwater flow in the intermediate water-bearing zone is northwesterly during both high and low tides. Wells WM-1M and WM-2M are down-gradient of EAL.

- The direction of groundwater flow in the deep water-bearing zone is between easterly to northeasterly during high and low tides. During two brief instances, it has been noted to swing easterly to southeasterly.

7.3.3 Horizontal and Vertical Gradients

- The horizontal gradient between shallow wells was not determined due to the complex groundwater flow conditions. The horizontal gradient in both the intermediate zone and the deep zone (MCA) is very low and ranges from approximately 0.0001 to 0.0005 feet/feet.

- The vertical gradient between the shallow and intermediate water bearing-zones is consistently downward.

- The vertical gradient between the intermediate and deep water bearing zones varies at each well triplet, however due to the presence of thick silts and clays between the Qp and the Kprm formations, it is likely that no significant groundwater movement is occurring between the intermediate and deep water-bearing zones.

7.4 GROUNDWATER QUALITY

Based on data collected from the first round of groundwater sampling, the following conclusions are drawn:

7.4.1 Shallow Wells

- The groundwater quality in the shallow wells do not appear to be affected by activities associated with the EAL.

7.4.2 Intermediate Wells

- Groundwater quality in the intermediate wells does not appear to be affected by activities associated with the EAL, with one possible exception (WM-1M).

- Groundwater quality in WM-1M, downgradient of the EAL, indicates the presence of benzene and 1,4-dichlorobenzene at levels above the MCL. These compounds were not detected in either the shallow or deep wells at location WM-1 which indicates that the vertical migration of contaminants from the intermediate water-bearing zone into the deep water-bearing zone seems unlikely. This may be attributed to the impermeable nature of the silty clay layer between the Qp and the Kprm formations. Arsenic was detected in two upgradient wells (WM-4M and WM-5M) at levels slightly above the MCLs. The presence of this compound is not attributed to the EAL.

7.4.3 Deep Wells

- Groundwater quality in the deep wells has not been affected by activities associated with EAL. Few organic compounds were detected in the deep wells, and none were detected above the MCL. The lack of contaminants also supports the conclusion of no significant downward groundwater movement. Beryllium was the only metal detected above the MCL in the deep wells. This metal was detected at a level only slightly above the MCL. The presence of beryllium in minerals associated with the stratigraphy beneath the EAL may contribute to the concentration of beryllium detected in groundwater samples collected from the deep wells at EAL.

SECTION 8

BIBLIOGRAPHY

Domenico and Schwartz. 1991. Physical and Chemical Hydrogeology. New York: John J. Wiley & Sons, Inc.

Fenneman, N.M. 1938. Physiography of Eastern United States. New York: McGraw-Hill Book Co., 381 pp.

Greenman, D.W., D.R. Rima, W.N. Lockwood, and Harold Meisler. 1961. Ground-water resources of the Coastal Plain area of southeastern Pennsylvania. Pennsylvania Geological Survey Water Resource Report 13, 375 pp.

Modjeski and Masters, Engineers. 1964. Soil Boring and Geotechnical Data prepared for the Commonwealth of Pennsylvania Department of Highways for the Construction of the Girard Point Bridge. 16 plates.

Owens, J.P. and J.P. Minard. 1979. Upper Cenozoic sediments of the lower Delaware Valley and the northern Delmarva Peninsula, New Jersey, Pennsylvania, Delaware, and Maryland. U.S. Geological Survey Professional Paper 1967-D, 47 pp.

Paulachok, G.N. 1991. Geohydrology and Groundwater Resources of Philadelphia, Pennsylvania. U.S. Geological Survey Water Supply Paper 2346, 79 pp.

Paulachok, G.N. and C.R. Wood. 1984. Water-table map of Philadelphia, Pennsylvania, 1976-1980. U.S. Geological Survey Hydrologic Investigations Atlas HA-676, 1 sheet, scale 1:50,000.

Quigley, P.A. 1994. Personal Communication to R. Scheinfeld on surface drainage direction.

Toffey, W.E. 1982. Philadelphia's river resources. Philadelphia City Planning Commission Technical Paper, 145 pp.

Roy F. Weston, Inc. 1979. Enterprise Avenue Landfill study, page 1: Report prepared for the City of Philadelphia Water Department, 120 pp. and Appendices.